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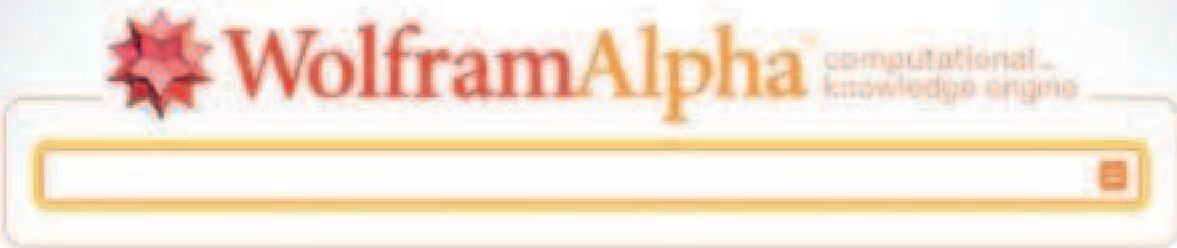

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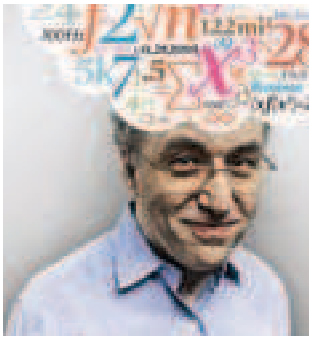

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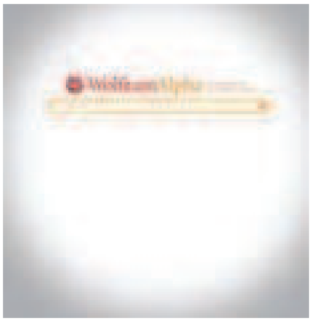

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CAN MEDIA MAKE MONEY ONLINE?
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2009

SIMSON GARFINKEL wrote this issue's essay, on privacy in the age of Facebook (*"Privacy Requires Security, Not Abstinence," p. 64*). He argues that in a time when people are simultaneously scared out of their wits about data theft and alarmingly cavalier about the exposure of their innermost secrets, we need to rethink what it means to maintain a private self while participating in a public life. "We need strong security for keeping our secrets safe from hackers and strong identification systems to make sure that we ourselves aren't locked out," he says. Garfinkel wrote his first article for *Technology Review* in 1989 and has been a regular contributor ever since. He published *Database Nation: The Death of Privacy in the 21st Century* in 2000. In 2003, as a PhD candidate at MIT, he spent a summer as a contractor working on the Defense Advanced Research Projects Agency's Total Information Awareness project. Garfinkel spent two years at Harvard as a postdoctoral fellow at the Center for Research on Computation and Society before becoming an associate professor at the Naval Postgraduate School in Monterey, CA, where he does research on computer forensics and data fusion.

PETER FAIRLEY reviews the European Union's effort to reduce carbon emissions through the market-based approach known as "cap-and-trade" (*"Carbon Trading on the Cheap," p. 72*). "Putting a price on carbon has become a mantra for how to go about stopping and reversing climate change. And it is a necessary step. But it is not sufficient," says Fairley. "The price has to be high enough to stimulate the long-term investments—like building nuclear reactors and carbon-capture plants—that will slash carbon emissions. Europe's experience shows that politicians are unwilling to set the cap tight enough to drive prices up." He adds, "When push comes to shove, politicians continue to err on the side of ensuring that the price doesn't get too high and hurt industry." A freelancer who regularly covers energy for *Technology Review*'s website, Fairley is now living in Paris. He writes for a number of magazines, including *Discover* and *IEEE Spectrum*.

ANDY KESSLER examines the likely impact of the economic stimulus bill's $19 billion in incentives for the advancement of health-care IT, electronic health records in particular (*"A Pound of Cure," p. 75*). Kessler, who worked on Wall Street for 20 years investing in Silicon Valley, suggests that for financial reasons, the medical industry is reluctant to use this technology to improve preventive care and increase accountability. "Everyone's first reaction to technology's effect on health care is always about medical records. But that should be easy—it's something even the airline industry has already done," he says. "Instead, I think the real breakthrough will come from keeping all of us from getting sick in the first place." Kessler is a former hedge fund manager who has written for the *Wall Street Journal*, the *New York Times*, *Wired*, *Forbes*, and the *Los Angeles Times*. His books include *Running Money*, *Wall Street Meat*, and *The End of Medicine*.

Photographer JASON MADARA shot this issue's photo essay, which examines the launch of the National Ignition Facility in Livermore, CA (*"Igniting Fusion," p. 24*). Scientists at Lawrence Livermore National Lab will attempt to create self-sustaining nuclear fusion using lasers; if they are successful, fusion could one day become a viable source of energy. "I was awed by the complexity and size of the construction," says Madara. His work has appeared in the *New York Times Magazine*, *Entertainment Weekly*, and elsewhere.

RANDI SILBERMAN (FAIRLEY)

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On Answers

FOUR KINDS OF SEARCH ENGINES

Search engines are knowledge systems that we ask, "What is known?" The answers we get reflect the questions the systems' designers allow, which in turn reflect designers' conceptions of what is knowable and useful to know.

The first search engines were not machines, and they didn't satisfy their users. The most famous of them all, the Oracle of Apollo at Delphi on the slopes of Mount Parnassus, issued prophecies for more than a thousand years. We possess more than 500 of the results of queries put to the Pythia, the priestess who presided over the Oracle. With exceptions, her answers were not helpful.

King Croesus of Lydia once asked the Oracle if he should wage war on the Persians, whose empire was expanding westward after a successful revolt against their rulers, the Medes. According to the historian Herodotus, the Pythia answered that if he did, he would destroy a great empire. Cautious, Croesus sent a large fee to the Delphians, and refined his search terms. He pressed: Would his reign be a long one? The answer, according to my battered Penguin translation by A. R. Burn, came back:

"When comes the day that a mule shall sit on the Median throne, then, tender-footed Lydian, by pebbly Hermus run and abide not, nor think it shame to be a coward."

Opaque—but Herodotus writes, "This reply gave Croesus more pleasure than anything he had yet heard; for he did not suppose that a mule was likely to become king of the Medes, and that meant that he and his line would remain in power forever." Alert readers will have guessed the end. Croesus went to war; the empire he destroyed was his own. Cyrus, the king of the Persians, was half Persian and half Mede, and thus a kind of mule.

The answers of the Delphic Oracle abound in these sorts of tricky occlusions. Whoever designed the system at Delphi believed or pretended to believe that the future was known to the god Apollo, who chose (as a demonstration of the mutability of human affairs) to deliver through his priestesses prophecies that were obscure, but that retrospectively provided dramatic satisfaction. A rationalist will suspect that obscure answers had another function: they could apply equally well to different outcomes. In any case, the turbidity of the Oracle's answers was its virtue.

In this month's cover story *("Search Me," p. 32)*, *Technology Review*'s chief correspondent, David Talbot, describes how the Web is usually searched: "Among all the leaders in Web search … the core approach has remained the same. They create massive indexes of the Web—that is, their software continually 'crawls' the Web, collecting phrases, keywords, titles, and links." Talbot examines some of the technical limitations of this method. But the notion that a search should produce a list of links to Web pages represents a view of what is knowable and what is useful to know that is as specific as that which made the Delphic Oracle. Traditional search is chaotically democratic. It assumes that the consensus view is the best, while rewarding the wayward answer by exposing it to the curious. The truths of traditional search are provisional. Popularity is virtue.

Our story describes a new kind of search engine, Wolfram Alpha. In fact, its inventor, the physicist and entrepreneur Stephen Wolfram, dislikes the word *search*: he calls it a "computational knowledge engine." Alpha, writes Talbot, is "meant to compute answers rather than list Web pages." It consists of "three elements … a constantly expanding collection of data sets, an elaborate calculator, and a natural-language interface for queries."

Alpha, too, represents a particular point of view—that of its creator. Wolfram's monumental book, *A New Kind of Science* (2002), explains how the complex world can be reduced to simple rules, and how those rules are computable. Alpha will be the first major application of his theories: an experiment to see how much of what is known can be expressed in straightforward answers.

About these fundamental questions, views differ. Ivan Herman of the World Wide Web Consortium tells Talbot, "Although I have graduated as a mathematician … I am not sure you can handle all of the miseries of this world by mathematical formula and computation." Another critic provides an example: "Imagine a question like 'Who are the most dangerous terrorists?' … Is someone a terrorist? How do we assess danger? And danger to whom? It's computationally very difficult to do that kind of reasoning."

Perhaps, speculates Daniel Tunkelang, the cofounder of the search company Endeca, there is a better way to approach the problem of building a search engine *(see "To Search, Ask," p. 13)*. "What we need is human-computer information retrieval. … Rather than guessing what users need, these tools provide users with opportunities to clarify and elaborate their intent. If the engine isn't sure what users want, it just asks them."

Now there's an alternative that is somehow shocking: Ask the questioner. Write and tell me what you think at jason.pontin@technologyreview.com. —*Jason Pontin*

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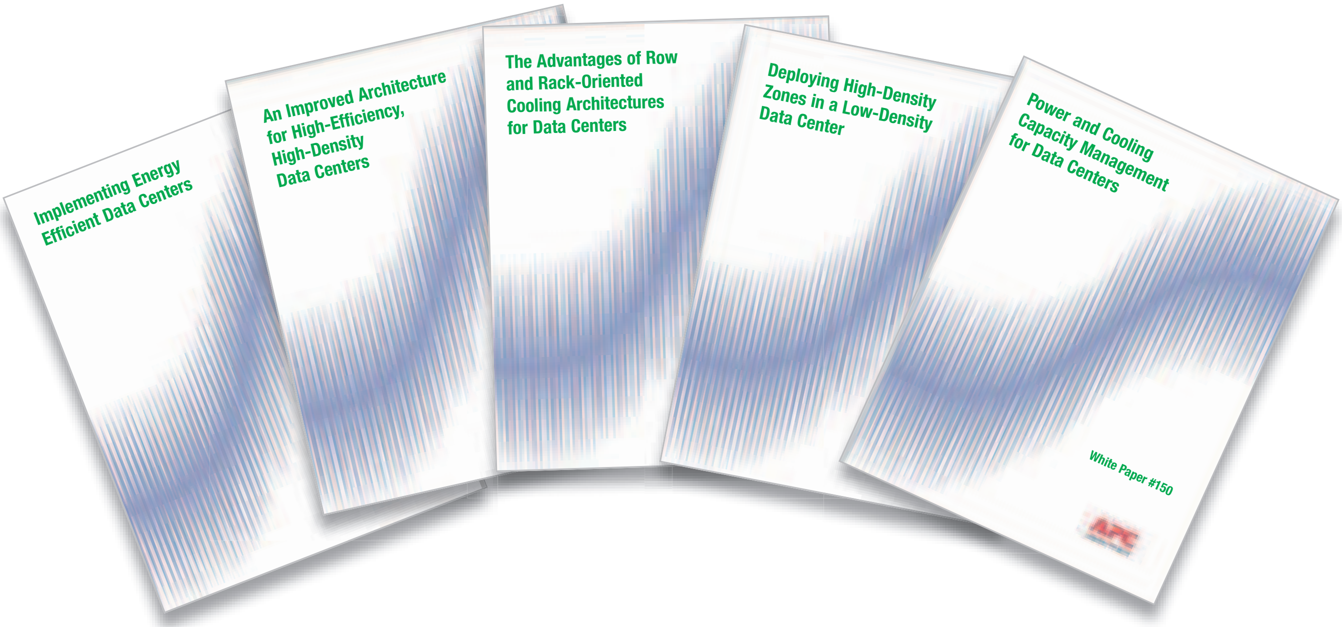

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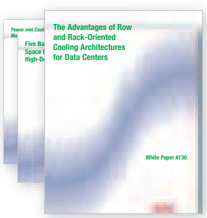

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TECH FUNDS

David Rotman's cover story on technology funding in the federal stimulus bill ("Can Technology Save the Economy?" May/June 2009) generated a lively discussion online, with many readers criticizing the legislation and its goals. One commenter objected less to the billions that will be spent than to who will be handing out the money:

May/June '09

The issue for innovation and economic stimulus is not with how much money is invested, or in what industries, but how and with whom. The problem is that our tech transfer system is fundamentally flawed due to the influence by the entrenched over our political system and federal government, resulting in what we've seen in industry after industry—incremental innovation, when in fact the signs are clear that we need revolutionary innovation. ... As this piece suggests, those of us on the front lines of real innovation—who are not too big to fail and are authentically attempting to overcome our many serious hurdles as a society—have nothing but barriers confronting us.

■ *markm on 04/21/2009 05:24 P.M.*

A letter writer took a different tack, lauding the stimulus package and making the case for why such massive investments are necessary if we are ever to transition to a sustainable economy based on renewable energy.

Economists should learn from the present crisis and stop thinking as if nothing has changed. New economies are emerging that will require more and more resources to support their growth, and if the development models inherited from the Industrial Revolution are not reconsidered, human activity will quickly deplete the inventories of nonrenewable resources and transform the biosphere into a dump.

Few people have a clear vision of the transition needed to implement sustainable models. The prime condition is to have an improved telecommunications network, so that knowledge can be distributed where it is needed, and not only where it makes financial sense for private telecommunication operators to put it. More generally, no sustainable development is possible without a massive investment in evenly distributed infrastructures. We have to replace the "bow and arrow" of our hunter-gatherer industrial civilization with the "plow and irrigate" distributed infrastructure of a sustainable clean economy. Only an emphasis on research and development can allow us to quickly achieve the right combination. And the technologies derived from this research will generate new jobs everywhere, because they will optimize the use of resources, including human resources. Yes, technology can save the economy—the sustainable economy that is the only ethical, decent reason we have to load future generations with huge amounts of debt.

Jean-Paul Vignal
Argyle, TX

BRAIN MATTERS

Emily Singer's article on drugs that can alter traumatic recollections ("Manipulating Memory," May/June 2009) had many readers pondering the ethical implications of the research.

The article gave me great hope for PTSD sufferers but also great fear for them, as well as for others who take the drugs. Surely during the effective period after taking drugs that block memory reconsolidation, they will have the same effects on other memories besides the ones that were deliberately brought to mind. If a PTSD sufferer undergoing the treatment thinks about his loved ones, will his love for them be lost or diminished? What about the many more people already taking propranolol? Are they losing their passion for arts, literature, their families, or their jobs just by thinking of those things while taking the drug?

Laurence Banner
Columbia, MD

Another reader sees a similarity between the way memories are handled in the brain and the way our bones adapt to external stimuli.

Emily Singer paints a picture of a brain that "erases" and then reconstructs memories (and presumably the physical synaptic underpinnings of memory as well).

I was amused by the several neuroscientists who expressed disbelief that the brain would handle memories this way, because this is precisely what our bones do every day of our lives. In an attempt to be most adaptable to input from the external environment, osteoclasts remove the hard substrate of bone, while osteoblasts lay it back down again.

If there is persistent strain in one direction, the new bone is laid down in a slightly different way each time, so that over a short period of time, the bone's shape changes by accommodating to the strain. If one views the brain as just another tissue adapting to a transient environment, it seems perfectly logical that memory reconsolidation functions in the same way: keeping what gets used and reused, and eventually overwriting or discarding that which is not recalled and needed. Sure, I wish I remembered more of the first 18 years of my life, but do I *need* that for managing today? Nope.

Bob Chapin
Preston, CT

ANONYMITY AND ITS DISCONTENTS

A few readers expressed worry over Tor, the technology described in David Talbot's article on anonymity software ("Dissent Made Safer," May/June 2009). One argued that "providing anonymity online effectively removes the one thing that stands in defense of a free Inter-

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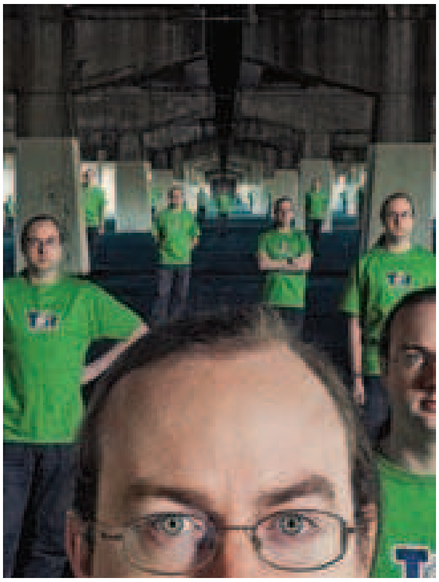

Roger Dingledine is the project leader of Tor, a system for anonymizing Internet communication.

net and freedom of speech—accountability." Another points out that Internet censorship is not just a problem for people in the developing world.

I was very disappointed by what I consider to be blatant cultural bias in David Talbot's article. The article cites government actions to filter or otherwise block Internet access by various Islamic countries, China, and Vietnam. But there was no mention whatsoever of actions by OECD countries to block online gambling (as in most U.S. states and some European countries) or hate sites (as in most European countries) or other types of content that is considered illegal or inappropriate according to national laws or customs (as in most countries around the world). I grant that the OECD countries do not usually use technical means to block websites, instead relying on laws. But such laws, and their enforcement, can be just as effective as technical means. Anonymity can be used to evade national laws as well as to evade technical barriers, so the issue is pertinent for all countries.

Richard Hill
Geneva, Switzerland

THE FUTURE OF JOURNALISM

Editor in chief Jason Pontin's diagnosis of the problems plaguing print publications in the age of blogs and citizen journalism ("A Manifesto," May/June 2009) ignited a contentious debate over how to save the traditional media and whether such an action is even desirable. The first reply to the expanded, online version of Pontin's manifesto thought his recipe for media's survival was a bit like rearranging the deck chairs on the Titanic.

Some very nice points. Still, these are really just minor adjustments, a bit of fine tuning that may get print orgs through the short term, but unless traditional publishers can overcome their editorial ego they will ultimately fail. A new paradigm is brewing and unless editors can accept the collaborative nature of their relationship with the reader—and do everything in their power to cultivate it—everything else is meaningless.

■ *mturro on 05/04/2009 at 9:26 P.M.*

Which received the response:

Pontin's observations about oversaturated circulation, advertising anarchy and commoditized content get at the root of what's troubling the mainstream media. He's not arguing for a return to the good old days, but rather pointing out that quality journalism does have a place in our society, along with other forms of media, and that business models need to change to support it. This is not a rant against unstoppable forces. It is an argument for accommodation and adaptation that preserves value.

■ *pgillin on 05/05/2009 at 8:11 A.M.*

Another commenter sees a technological solution around the corner:

Seems to me that everyone is looking in the wrong direction. Laser and inkjet printing technology keeps getting cheaper. With some innovation, a printer that incorporates duplexing and folding could provide an on-demand printed version of a daily newspaper, ready to go with a morning cup of coffee.

■ *zozazumi on 05/05/2009 at 4:03 P.M.*

A reader stresses the importance of communicating to the public what professional journalism is all about, and how valuable it can be when done well.

As a former print journalist who now teaches at the Southern Alberta Institute of Technology in Calgary, one of the things I try to teach my students is that doing real journalism is hard work. It takes two full years to get across to them the difference between simply sitting down in front of a computer and tapping something out, and doing the sort of true research that journalism demands. That research—meeting people face to face, asking good questions, deciding what is credible and what is spin, separating new information from old, making it interesting—is tough. But it is something good journalists are paid to make look easy.

If publishers then give this content away instead of charging for it, readers are persuaded that news is essentially worthless and anyone can do it. Add in the fact that many powerful people also find journalism too intrusive for their tastes, and you have a craft that is under stress as never before.

So along with finding a business model that will allow real journalism to survive, we have to figure out how to teach our readers what journalism actually is, and how to tell the difference between it and the tidal wave of undifferentiated information flooding our lives every day. And we need to use every available means to make these arguments before the doomsayers' prophecies become self-fulfilling.

Jim Cunningham
Calgary, Alberta

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NOTEBOOKS
Expert opinion

ENERGY

Potemkin Trading

CAP-AND-TRADE ALONE WON'T CURB EMISSIONS, SAYS DAVID G. VICTOR.

After years of delay, the United States is finally trying to tame the emission of gases that lead to global warming. The most likely outcome is some kind of cap-and-trade system that aims to put a lid on these greenhouse-gas emissions and allows firms to trade emission credits.

The European cap-and-trade system, known as the Emission Trading System (ETS), is the world's largest pollution market, and it offers important lessons for U.S. policymakers *(see "Carbon Trading on the Cheap," p. 72)*. One lesson rings louder than all the others: cap-and-trade, by itself, won't make much of a dent.

Over most of the ETS's history, prices have been so low that electric utilities have found it cheaper to run their coal-fired power plants than to switch to less polluting natural gas. And prices have been far too low to encourage a big shift away from conventional technologies. Politicians could fix that by tightening the caps on emissions and driving up prices, but even hypergreen Europe hasn't had the political stomach to do that. Economists love pollution markets for the same reason that politicians are wary: they make real costs transparent. But the ETS is little more than a Potemkin market.

The same political logic is now playing out in the United States. When the Obama administration first outlined its budget in February 2009, it assumed that credits might trade at around $14 per ton of greenhouse gas. (That's the equivalent of little more than a dime per gallon of gasoline—so low that few consumers will notice. The energy markets, on their own, cause much bigger price swings.) The legislation now taking shape in Congress may yield prices whose practical effect will be even smaller. And with the economy still weak, it is hard to see how politicians anywhere will tighten the screws and raise carbon dioxide prices high enough to make a difference.

Behind the façade, cap-and-trade isn't having much impact because politicians prefer to rely on direct regulation. In Europe, in fact, only about half of emissions are even included in the ETS; dozens of agencies use direct regulation to tame all the rest, including almost all the emissions from transportation and buildings. Even in the power sector, which is part of the ETS, the biggest changes in technology, such as the rapid spread of wind turbines, are unfolding in response to special "feed-in tariffs" and other regulatory policies rather than to the market signal of the ETS.

America's cap-and-trade system is likely to follow the same path. When Congress completes its political handiwork, the outcome will be a beautiful patchwork of low carbon prices along with a host of stealthy regulatory policies, such as mandates for renewable power and energy efficiency, and subsidies for favored low-emission technologies. Analysts should pay less attention to the elegant (but largely irrelevant) markets and focus more closely on the regulations. Global warming is a serious problem, but the political process is geared to evade the fact that fixing it won't be cheap. TR

DAVID G. VICTOR IS A PROFESSOR AT THE SCHOOL OF INTERNATIONAL RELATIONS AND PACIFIC STUDIES AT THE UNIVERSITY OF CALIFORNIA, SAN DIEGO.

MEDICINE

Cell Fate

JEANNE LORING EXPLAINS WHY WE CAN'T ABANDON EMBRYONIC STEM CELLS.

It was in Toronto, in the summer of 2006, that stem-cell research was turned upside down. I remember it clearly, but I didn't feel the earthquake at the time: a youngish, earnest Japanese

researcher named Shinya Yamanaka gave a talk at the annual meeting of the International Society for Stem Cell Research, reporting that he could make mouse skin cells look and act like embryonic stem cells just by adding a few genes. The following year, both Yamanaka and Rudolf Jaenisch, a well-respected stem-cell researcher from MIT, reported that these induced pluripotent stem cells (known as iPS cells) passed the litmus test for pluripotency, or the ability to

BOB LONDON

differentiate into all types of cells: when mouse iPS cells were injected into mouse embryos, the cells were incorporated into the developing mice.

Since then, research based on iPS cells has exploded *(see "Medicine's New Toolbox," p. 40)*. Like embryonic stem cells, iPS cells can give rise to different types of tissue, but they offer a way to avoid both the ethical and practical hurdles of dealing with human embryos. Scientists have made human iPS cells from skin and hair follicles, as well as from tissue harvested from people with various ailments. Methods for making these cells are evolving at breakneck speed; the most recent development, as of this writing, is the transformation of human skin cells into iPS cells using proteins rather than the currently most common approach of genetic engineering.

Given the rapid successes of iPS-cell research, some have argued that we should abandon human embryonic stem cells. This is a very bad idea. We should continue, and even intensify, the study of these stem-cell lines.

We know much more about embryonic stem cells than we do about iPS cells. The relatively few embryonic-stem-cell lines in existence have been well characterized by many scientists. However, the rapidly growing number of iPS-cell lines, and the new methods of deriving them, have overtaken our capacity for characterizing them. There are too many iPS-cell lines to count, much less analyze.

Some iPS-cell lines are likely to bear close resemblance to embryonic stem cells. But others will be clearly different—perhaps more or less prone to develop into tumors, or with different degrees of potential for differentiation. IPS cells may be better than embryonic stem cells for some uses, but worse for others. We have to find out, not just guess, because people's health is at stake.

I embrace the new technologies, and I want to use them all, but we still need to pick the right cells for the right jobs. IPS cells and embryonic stem cells must be compared, directly, by a lot of scientists in a lot of ways before we can think seriously about what cells to use for medical applications. TR

JEANNE LORING IS FOUNDING DIRECTOR OF THE CENTER FOR REGENERATIVE MEDICINE AT THE SCRIPPS RESEARCH INSTITUTE IN LA JOLLA, CA.

INFORMATION

To Search, Ask

LIBRARY SCIENCE WILL IMPROVE ONLINE SEARCH, SAYS DANIEL TUNKELANG.

If you ask a librarian for a book about Mexico, the librarian will undoubtedly ask you to specify: Are you looking for a history book, a travel guide, or something else entirely? Today's search engines could benefit from the same approach.

With most existing online systems, a user makes an information request in a couple of words, and the search engine returns a list of documents ranked by relevance. Search technologists are busily working on relevance-ranking algorithms and question-answering systems so that they can read as much as possible into a query without asking any more of the user. But information-retrieval researchers suggest that these approaches have reached a point of diminishing returns. A search engine cannot reliably surmise the user's intent from a single query.

What we need is human-computer information retrieval (HCIR), a term coined by University of North Carolina professor Gary Marchionini. The HCIR approach advocates for tools that bring human intelligence and attention actively into the search process. Rather than guessing what users need, these tools provide users with opportunities to clarify and elaborate their intent. If the engine isn't sure what users want, it just asks them. *(For another approach to information retrieval, see "Search Me," p. 32.)*

The HCIR approach evokes what librarians call reference interviews. Indeed, HCIR leans heavily on techniques from library science, such as faceted information retrieval. Adapted for Internet use over the past decade, faceted search extends keyword search by allowing users different ways to refine queries. A search for "Mexico" might offer refinements by topic (history, demographics), language (Spanish), date published, and so on. Not surprisingly, this approach is popular for online libraries, but it has also become a staple of online shopping; Home Depot's website is an example. HCIR transforms search engines from black-box matching engines to conversational librarians. The core technical challenge is no longer ranking the results but, rather, summarizing and organizing them so that users can interact with them. HCIR offers users the transparency, control, and guidance to establish, elaborate, and resolve their information needs.

It's fun to work on algorithms that guess users' intentions, and the temptation to push the limits of purely technical solutions can be irresistible. But sometimes the best approach is the most obvious one. We may do well to follow a bit of advice passed on by Nobel laureate Richard Feynman in his book *Surely You're Joking, Mr. Feynman!* When discussing with a bar mate how best to pick up women, Feynman recounts, that sage soul averred, "You just ask them." TR

DANIEL TUNKELANG IS COFOUNDER OF ENDECA, AN INFORMATION AND SEARCH COMPANY.

FUEL CELLS

BUTANE CHARGER

SOLID-OXIDE fuel cells can generate electricity using a range of readily available fuels. But because they run very hot—often above 1,000 °C—they typically require insulation that makes them bulky. A new version employs an insulation technique that keeps the finished device as small as a pack of playing cards. The gadget, which could help keep electronic devices humming on long flights or hikes, runs on cheap butane cartridges; one cartridge packs enough power to recharge a smart phone 20 times. Swap out the cartridge, and it's ready for 20 more charges. The device is scheduled to go on sale next year.

Product: Fuel-cell recharger **Cost:** Initially between $100 and $200; cartridges will cost between $1 and $3. **Source:** www.lilliputiansystemsinc.com **Company:** Lilliputian Systems

CHRISTOPHER HARTING

PHOTOVOLTAICS

Power Booster

IF JUST one solar panel in a rooftop array falls under shade, the performance of all of the panels typically drops. That's because an array's electrical voltage and current are usually set at just one point: the inverter that changes direct current to alternating current. The settings the inverter can choose are determined by the worst-performing solar panel. National Semiconductor of Santa Clara, CA, has developed power management circuitry that adjusts the voltage on each panel to match its power output. Field tests show that the gadget can reduce losses from unshaded panels by 57 percent.

Product: Solar Magic
Cost: $199
Source: www.solarmagic.com
Company: National Semiconductor

NANOTECHNOLOGY

QUANTUM-DOT LIGHTING

LIGHT-EMITTING DIODES (LEDs) are highly efficient, but they can't directly produce white light. Though a blue LED can be coated with a phosphor that alters some wavelengths to yield a whitish mix, the resulting light has a bluish cast, and some energy is wasted as heat in the process. A new LED lamp avoids this problem by using an optic coated with quantum dots—bits of semiconductor material a few nanometers in diameter. When excited by a light source, the dots radiate light in wavelengths that vary according to their sizes. The optic—coated with dots in specific sizes and ratios—appears orange when the light is off (left) but radiates white light when the underlying blue LED is on (right). The result: LED lamps that are 50 percent more efficient and produce better-quality white light.

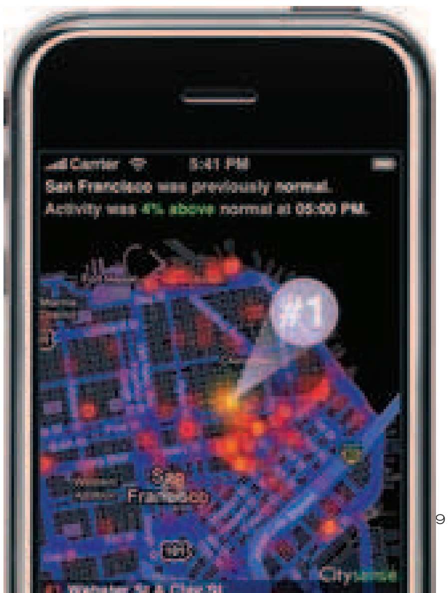
Product: Array lamp with Quantum Light optic **Cost:** About $100 per lamp **Source:** www.nexxuslighting.com, www.qdvision.com **Company:** Nexxus Lighting, QD Vision

WIRELESS

(PEOPLE LIKE) YOU ARE HERE

NEW SOFTWARE can tell mobile-phone owners, in real time, where to find people with similar backgrounds and interests—students, tourists, or businesspeople, for instance. The software, called Citysense, acquires data from users who opt in. Their profiles and their movements throughout the city, as recorded by the GPS chips on their mobile devices, are logged in a database. (It also takes in feeds from other applications that record real-time location data.) The software removes personal information but records activity patterns so that users can find hot spots of activity among their peers, as determined by the activities of other users.

Product: Citysense **Cost:** Free **Availability:** San Francisco now (version 1.0); San Francisco and another city (New York or London) later this year (version 2.0) **Source:** http://www.citysense.com **Company:** Sense Networks



COURTESY OF NATIONAL SEMICONDUCTOR (BOOSTER); BRUCE PETERSON (BULB); COURTESY OF SENSE NETWORKS (CITYSEARCH)

HEALTH

WIRELESS SCALE

THIS SCALE allows users to wirelessly transmit their weight and body-fat measurements to any Bluetooth-enabled device. A Bluetooth adapter comes with the scale; once it is plugged into a computer's USB port, the scale will automatically sync with the computer and send new data to it. Accompanying software allows people to track and graph their weight and body-fat composition. The scale is also compatible with Microsoft's HealthVault, an online service for storing and organizing personal health records.

Product: BC-590BT Wireless Body Composition Monitor **Cost:** $249.99
Source: www.thecompetitiveedge.com **Company:** Tanita

INTERFACES

WAVING THE CHANNEL

TELEVISION VIEWERS will soon be able to change channels with a wave of the hand. A new TV set with a chip-based infrared sensor embedded in its front maps the depth of objects in the room, making it possible to detect hand motions—even when the lights are low. A sharp wave powers up the set; a circular motion flips the channel; an up-and-down motion controls volume. The product is expected to be available in 2010.

Product: Hitachi gesture-recognition television **Cost:** Not available **Source:** www.canesta.com
Companies: Hitachi, Canesta

DIAGNOSTICS

Glaucoma Detector

A NEW device uses computer vision to help doctors more quickly and accurately test patients for glaucoma. In some current tests for vision loss, patients report when they see a light at the periphery of vision, but this subjective method is error-prone and can make diagnosis tricky. The TrueField Analyzer measures the tiny contractions of a patient's pupils as they respond to a light pattern emitted by the device. By recording the pupils' movements, it can determine areas of reduced vision sensitivity. The device, which can test both eyes at the same time, is expected to reach the market by the end of this year.

Product: TrueField Analyzer
Cost: Not available
Source: www.truefield-analyzer.com
Company: Seeing Machines

BRUCE PETERSON (SCALE); COURTESY OF CANESTA (TV); COURTESY OF SEEING MACHINES (GLAUCOMA)

POLYMERS

CHEAPER CHEMICAL SENSOR

A NEW portable sensor system detects airborne organic chemicals about as accurately as a $25,000 machine confined to a lab. The device's sensor element (above) holds an array of polymers deposited between capacitance plates; their ability to store electrical charge changes in specific ways when certain molecules are absorbed, enabling the device to identify those agents. The system incorporates a polymer called BSP3, invented at Pacific Northwest National Laboratory, that is especially responsive to compounds such as nerve agents and certain pesticides.

Product: SeaPORT SC-210 **Cost:** About $3,000
Source: www.seacoastscience.com **Company:** Seacoast Science

TRANSPORTATION

First Plug-In Hybrid for U.S. Sale

WHILE MANY automakers are developing plug-in hybrids, the first model sold in the United States is likely to be the Karma, made by the startup Fisker of Irvine, CA, and scheduled for its first sales in the summer of 2010. (Toyota says it will lease 500 plug-in Prius models worldwide for testing this year, including 150 in the United States, and GM says its Chevy Volt will go on sale in November 2010.) Once the Karma has been plugged in to charge, the luxury four-passenger sedan can run on batteries alone for 50 miles. After that, an onboard gasoline generator kicks in to recharge the battery, extending the range by 250 miles. Two 150-kilowatt electric motors together deliver 403 horsepower—enough for the car to reach 60 miles per hour in 5.8 seconds in "sport" mode, which uses power from both the battery pack and the gas-powered generator. "Stealth" mode relies exclusively on electricity.

Product: Karma
Cost: $87,900
Source: karma.fiskerautomotive.com
Company: Fisker Automotive

OPEN-SOURCE

FIREFOX GOES MOBILE

FIREFOX, the open-source Web browser, holds nearly a quarter of the market. Now a mobile version called Fennec is coming. Like Firefox, Fennec allows developers–of which there are about 8,000–to add functions such as bookmark-synchronizing tools and video players. In addition, designers are trying to make navigation simpler; the "Awesome Bar," for example, drops down a list of recently visited sites or recently searched terms. Mozilla has already released a version for Nokia's N810 tablet computer; later this year it plans to roll out a version for Windows Mobile, as well as for phones that run the Symbian operating system.

Product: Fennec browser **Cost:** Free **Source:** https://wiki.mozilla.org/fennec **Company:** Mozilla

BRUCE PETERSON (SENSOR); COURTESY OF FISKER AUTOMOTIVE (CAR); COURTESY OF MOZILLA (FIREFOX)

MEDICINE

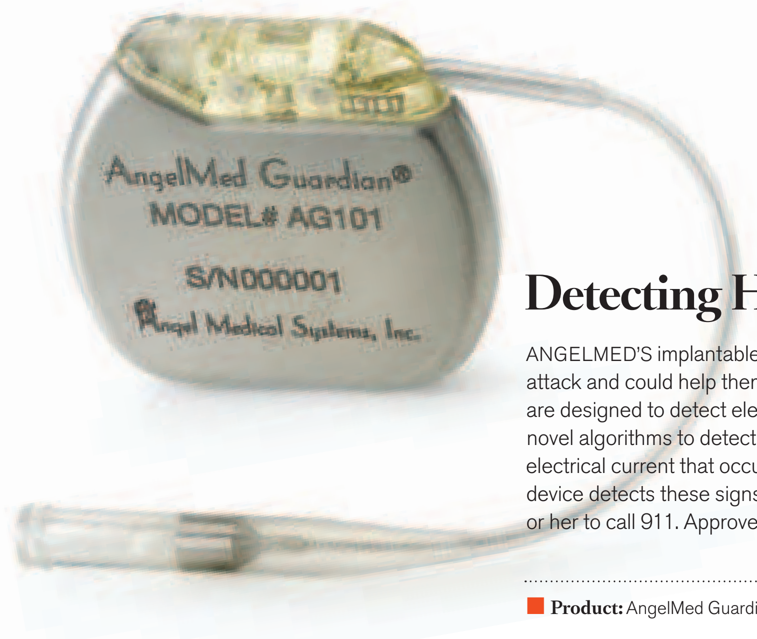
HEART WATCHERS

New wireless sensors and diagnostic algorithms promise simpler ways to remotely monitor cardiac patients for early warning signs of heart failure or heart attack.

MONITORING HEART FAILURE

A 15-CENTIMETER wireless sensor (right) approved this spring by the U.S. Food and Drug Administration is part of a monitoring system now being marketed. The system spots signs of heart failure by detecting fluid buildup in the lungs and elsewhere in the body—a hallmark of heart failure—and analyzing the patient's activity levels, heart rate, and respiration. When attached to a patient's chest, it beams data to a special cell-phone-like gadget in the person's pocket or somewhere nearby. From there, the information is wirelessly transmitted to the company's servers. Algorithms detect anomalies, and physicians receive the data via the Web or a mobile device.

Product: PiiX sensor device; zLink portable transmitter **Cost:** $400 to $700 **Source:** www.corventis.com **Company:** Corventis



Detecting Heart Attacks

ANGELMED'S implantable device (left) alerts high-risk patients when they show signs of a heart attack and could help them get medical attention sooner. Whereas existing implantable devices are designed to detect electrical irregularities in the heart, known as arrhythmias, this device uses novel algorithms to detect problems with blood flow. The device picks up a subtle abnormality in electrical current that occurs when one of the coronary arteries is blocked by a clot. When the device detects these signs of heart attack, it generates a buzz that the patient can feel, alerting him or her to call 911. Approved in Brazil, the device is undergoing clinical testing in the United States.

Product: AngelMed Guardian System **Cost:** Not available **Source:** www.angel-med.com **Company:** AngelMed

BRUCE PETERSON (CORVENTIS); COURTESY OF ANGELMED

Technology Review's Career Resources

Career Resources brings you success stories from executives who continued their education, essential advice from experts on how to achieve your career goals, and a directory of programs designed specifically for the working professional. **www.technologyreview.com/careerresources/.**

Career Growth Profile

IRENE POH

Age: 29

Job Title: Senior Business Analyst

Employer: Procter and Gamble

Graduate Programs: MBA, finance and strategy, University of Chicago, 2008; MEng, operations research and industrial engineering, Cornell University, 2002; BS, policy analysis and management, Cornell University, 2001

Like most undergraduates, Irene Poh wasn't sure what she wanted to be "when she grew up." One thing she did know, however, was that she was a "quant at heart." Quantitative subjects such as mathematics and statistics spoke to her. Poh felt strongly that her career would draw upon her passion for analysis.

Today, at age 29, she is a senior business analyst for Procter and Gamble, providing advisory and consulting services to P&G hair-care marketing teams across North America.

"I work with the various business leaders to provide strategic and tactical recommendations on how to solve some of their highest-priority business problems," Poh explains.

Poh attributes her solid footing in both qualitative and quantitative skills to her bachelor's degree in policy analysis and management and her master's degree in research and industrial engineering from Cornell University.

"Both degrees are about solving difficult programs and influencing decision makers and/or policy makers at critical moments," says Poh, who says her master's degree also helped her command a higher starting salary when P&G hired her straight out of school.

Three years into her career, however, Poh decided she needed more schooling, and a master's degree in business administration seemed to fit the bill.

"The business world is competitive, and education is an asset that nobody can ever take away from you," Poh says. "The University of Chicago is a very analytical program, with strengths in finance and economics. These were areas that supplemented my work in P&G's business analytics organization; I felt that I could benefit from the formal training in finance and business strategy."

Poh weighed these factors when exploring graduate schools:

- **Type of program:** Poh didn't want to go back to school full time, so she opted for a weekend MBA program.
- **School's reputation and areas of specialty:** Is the school recognized in your industry? Does it offer programs that are relevant to your work?
- **Flexibility of the program:** Can you choose your courses, or is there a set curriculum?
- **Commute time:** Poh commuted on Saturday mornings from Cincinnati to Chicago because the program offered exactly what she wanted. However, she admits there are disadvantages to attending a school outside your hometown. "Staying local gives you the ability to build a strong local network of peers and professors," she says. "[When you commute], doing projects and socializing becomes a lot harder during the rest of the week. If you end up traveling for school, find a carpool or buddy to share travel costs and driving with." Poh adds that participating in a carpool allowed her and her peers to use the commute time for group studying.

To learn more about Irene's decision to continue her education—and how it helped her move up the corporate ladder, go to **www.technologyreview.com/careerresources/.**

Program Directory

NYU·poly
POLYTECHNIC INSTITUTE OF NYU
EXECUTIVE MASTER'S PROGRAMS IN TECHNOLOGY MANAGEMENT

Polytechnic Institute of NYU Executive Master's Programs

Based in New York City and Westchester, NY, Polytechnic Institute of NYU's fast-track executive master's programs in Management of Technology and Information Management enable professionals to move beyond pure technology and become effective managers of innovation. Participants gain knowledge that is increasingly valuable to firms and not easily outsourced. Join us for an info session and get complete details at: http://www.mot-im.poly.edu

To list your program or recruitment ad in our Career Resources section, e-mail Barry Echavarria at barry.echavarria@technologyreview.com or call 603-924-7586.

Q&A

ALLISON MACFARLANE

Life after Yucca

In 1982, the U.S. government formally accepted the dirty job of finding a place to dispose of highly radioactive nuclear waste, including spent reactor fuel, which will remain radioactive for hundreds of thousands of years. Five years later, Congress directed the U.S. Department of Energy to begin seriously investigating a single site—Yucca Mountain, NV—as a permanent geological repository. But earlier this year, with 60,000 metric tons of spent fuel clogging storage facilities at power plants, the Obama administration announced that it would cut Yucca's funding and seek alternatives.

Allison Macfarlane, a geologist at George Mason University and the editor of *Uncertainty Underground: Yucca Mountain and the Nation's High-Level Nuclear Waste*, is a leading technical expert on nuclear-waste disposal who recently sat on a National Research Council committee evaluating the Department of Energy's nuclear-power R&D programs. She spoke with David Talbot, *Technology Review*'s chief correspondent, about the future of nuclear waste—and what it means for the future of nuclear power.

TR: You are known as a Yucca critic. Does this mean you oppose nuclear power?

Macfarlane: Not at all. From the point of view of climate change, we absolutely, definitely need nuclear power.

Only last year, the Bush administration filed the necessary application with the Nuclear Regulatory Commission to construct Yucca. Now Obama's energy secretary, Steven Chu, says Yucca is "off the table." Is it really unsuitable?

Yes. The area is seismically and volcanically active. More significantly, the repository would have an oxidizing environment—meaning materials there would be exposed to free oxygen in the air. Neither spent nuclear fuel nor canister materials are stable in such an environment in the presence of water. The United States is the only country that is considering a repository in an oxidizing environment.

Then why was Yucca Mountain the government's choice for 22 years?

Mostly political reasons. Originally three sites were considered: Yucca, and ones in Texas and Washington State. Congress balked at the price tag of characterizing three sites at once. In the ensuing fight to keep the waste program alive, Nevada was the politically weakest of the three and lost the battle.

Politics helped end the matter, too. Nevada's senior senator, Harry Reid, is now Senate majority leader and has long opposed Yucca.

Maybe—but the technical objections are serious and real.

Will the administration's decision stall any renaissance in nuclear energy?

No. There's no historical example showing that a lack of a plan for nuclear waste will halt the progress of nuclear energy.

What now?

Within the next five years, almost every nuclear power plant will have dry-cask storage: the waste will be moved from storage pools to outdoor concrete-and-steel casks inside plant security perimeters. As an interim solution, that's quite safe. But eventually the casks will corrode and break down and release radioactive material into the environment, though it will probably take hundreds of years. That's why we need geological storage.

What's the right geology?

Waste should be stored in a reducing environment [one not exposed to free oxygen], and this usually means underneath the water table, though salt formations can be reducing even if they are not below the water table. The Swedes and Finns are planning to put their waste inside granite and metamorphic rock, and the storage casks will be below the water table. And that's all okay. Spent fuel—which is just uranium dioxide, fission products, and actinides [radioactive elements, including plutonium]—is relatively stable under such conditions. With no free oxygen, it just sits there.

Will we still need such storage even if future reactors burn more of the plutonium—or even if future generations decide to reprocess some of the old spent fuel to recover plutonium?

Yes. The French reprocess spent fuel, but they still need a repository. They are doing research on a site at Bure, in northeast France. It has a kind of sedimentary rock that's relatively fine grained, and it's a reducing environment.

So where are the suitable storage locations in the United States?

There are lots, all over the country.

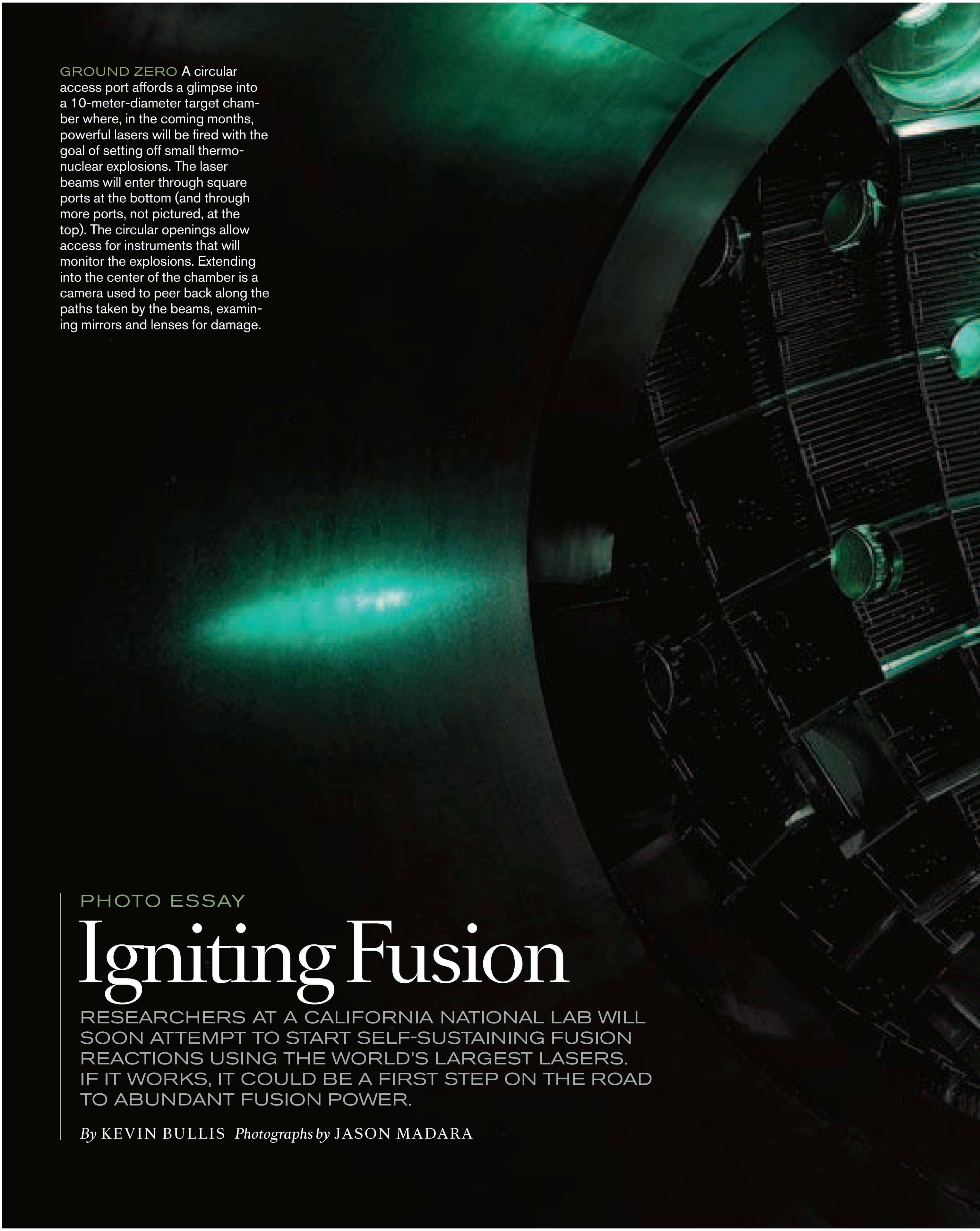
Then it should be easy to name two or three.

I haven't studied anything in detail, and I don't want to get anybody upset. But we have a huge country, and there are many locations. One thought, though, is that sites could be in locations where people already have a comfort level with nuclear power, which is how the Swedes and Finns have been successful.

It took 22 years and $8 billion to get nowhere on Yucca. Politics aside, how long will it take, and how much will it cost, to get U.S. storage sites opened?

We didn't get nowhere. We learned quite a bit. We should set aside something on the order of a few decades to get this right. It will cost billions, but that's part of the price of nuclear power. TR

Photograph by CHRIS CRISMAN



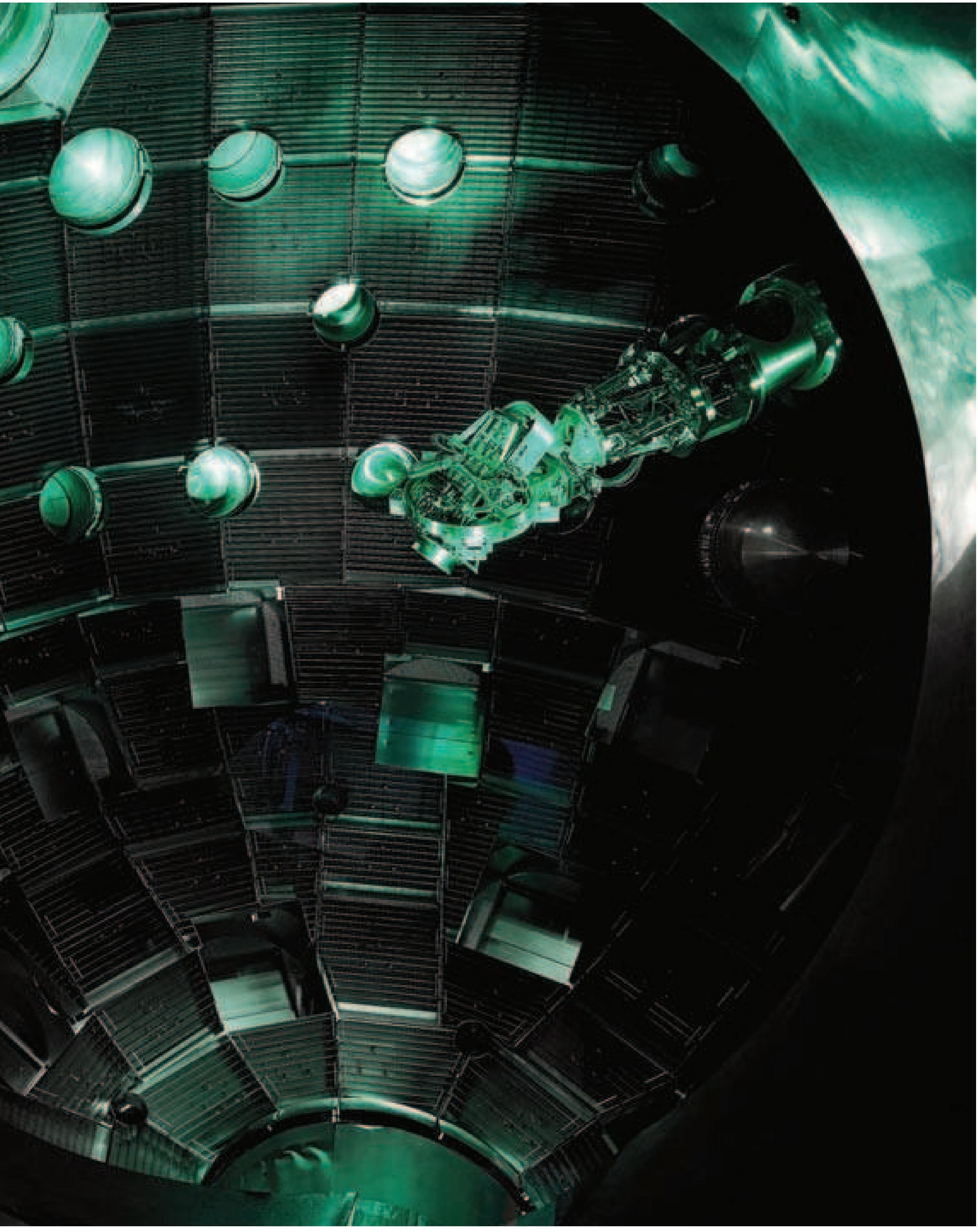
GROUND ZERO A circular access port affords a glimpse into a 10-meter-diameter target chamber where, in the coming months, powerful lasers will be fired with the goal of setting off small thermonuclear explosions. The laser beams will enter through square ports at the bottom (and through more ports, not pictured, at the top). The circular openings allow access for instruments that will monitor the explosions. Extending into the center of the chamber is a camera used to peer back along the paths taken by the beams, examining mirrors and lenses for damage.

PHOTO ESSAY

Igniting Fusion

RESEARCHERS AT A CALIFORNIA NATIONAL LAB WILL SOON ATTEMPT TO START SELF-SUSTAINING FUSION REACTIONS USING THE WORLD'S LARGEST LASERS. IF IT WORKS, IT COULD BE A FIRST STEP ON THE ROAD TO ABUNDANT FUSION POWER.

By KEVIN BULLIS *Photographs by* JASON MADARA



It's late April and workers are assembling the last parts of the National Ignition Facility (NIF), a sprawling building covering the area of three football fields at Lawrence Livermore National Laboratory in Livermore, CA. Dressed in hard hats, hair nets, lab coats, and latex gloves, they have gathered at the target chamber, a sphere 10 meters in diameter and bristling with 48 burnished-aluminum ducts that together house 192 separate laser beams. Each beam on its own is one of the world's most powerful, says Bruno Van Wonterghem, operations manager at NIF. Together they deliver 50 to 60 times the energy of any other laser.

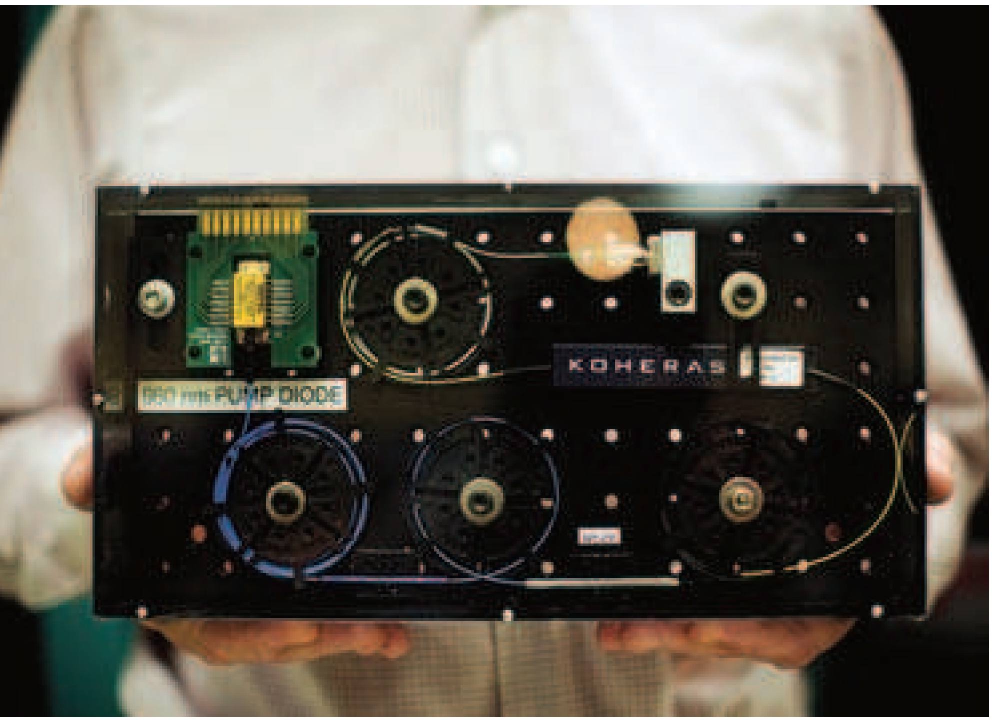
The workers are preparing to install a key piece of equipment—the target-alignment sensor—at the end of a tapered boom that can be extended into the center of the chamber. Scientists will use the sensor to position a gold canister the size of a pencil eraser at the center of the sphere and align it with the laser beams. In a series of experiments over the coming months, if all goes according to plan, those lasers will strike the gold canister with a pulse 3 to 20 nanoseconds long, generating a bath of high-energy x-rays. These in turn will cause a two-millimeter pellet containing hydrogen isotopes to implode. "All of that kinetic energy gets transformed into heat," says Van Wonterghem. The hydrogen pellet will reach a temperature of 100 million °C and a density 100 times that of lead—enough to start a fusion reaction.

Fusion, in which atomic nuclei combine to form atoms of a new element, is the key reaction fueling nuclear bombs and the sun. (In the NIF experiments, hydrogen isotopes combine to form helium nuclei while releasing neutrons and x-rays.) It has also long been held up as a potential source of abundant energy, if only the reactions could be harnessed in a controlled setting. That's challenging, because a plasma hot enough for hydrogen nuclei in it to fuse is so hot that it would destroy any containment material. Scientists have conceived two general solutions. The first and most mainstream is to confine the plasma in a powerful electromagnetic field. That is what's supposed to happen at the multinational, $14 billion ITER project in France, which is expected to be operational by 2018.

NIF takes a fundamentally different tack. By using lasers to compress the hydrogen fuel, it will mimic the extreme heat and density inside a star. The resulting fusion reaction is controlled not by confining it electromagnetically but by limiting the amount of fuel. NIF will produce a tiny thermonuclear explosion, so small that it can be studied in a 10-meter chamber. In fact, NIF's primary mission is to shed light on high-temperature and high-density physics, including the reactions in nuclear weapons, by re-creating conditions inside stars and bombs.

Researchers debate which approach will be the most useful for generating electricity; so far it's too early to be sure. But it looks likely that NIF will be the first facility to reach a significant milestone in the quest for laser-based fusion power: the ignition of a self-sustaining reaction that produces more energy than was put in by the laser. Previous experiments and computer simulations suggest that the 192 lasers at NIF are powerful and precise enough to set off such a chain reaction—one that will continue to burn until the hydrogen fuel runs out.

There are still huge challenges to be met before fusion can be harnessed to generate electricity. But achieving controlled fusion burn "will be an incredible event," says Edward Moses, a principal associate director at Livermore who's in charge of NIF. "We think we're coming to a new era."



FIRING LASERS

Igniting fusion won't be easy. It requires a facility that can marshal vast amounts of power but control it so precisely that it can be aimed at targets measured in micrometers. That, says Ian Hutchinson,

LIGHT SHOW The enormous lasers start as a 50-micrometer-wide beam generated inside fiber-optic coils (opposite) and fed by light from a simple diode. The initial pulse is amplified 10,000 times and split into 48 beams. Each beam is then delivered to its own "preamplifier," one of which is shown here in a maintenance room. The preamplifiers, which are transported on a system of rails, amplify the lasers 20 billion times. At this stage, each beam travels inside the steel tubes seen above and then is split four ways.

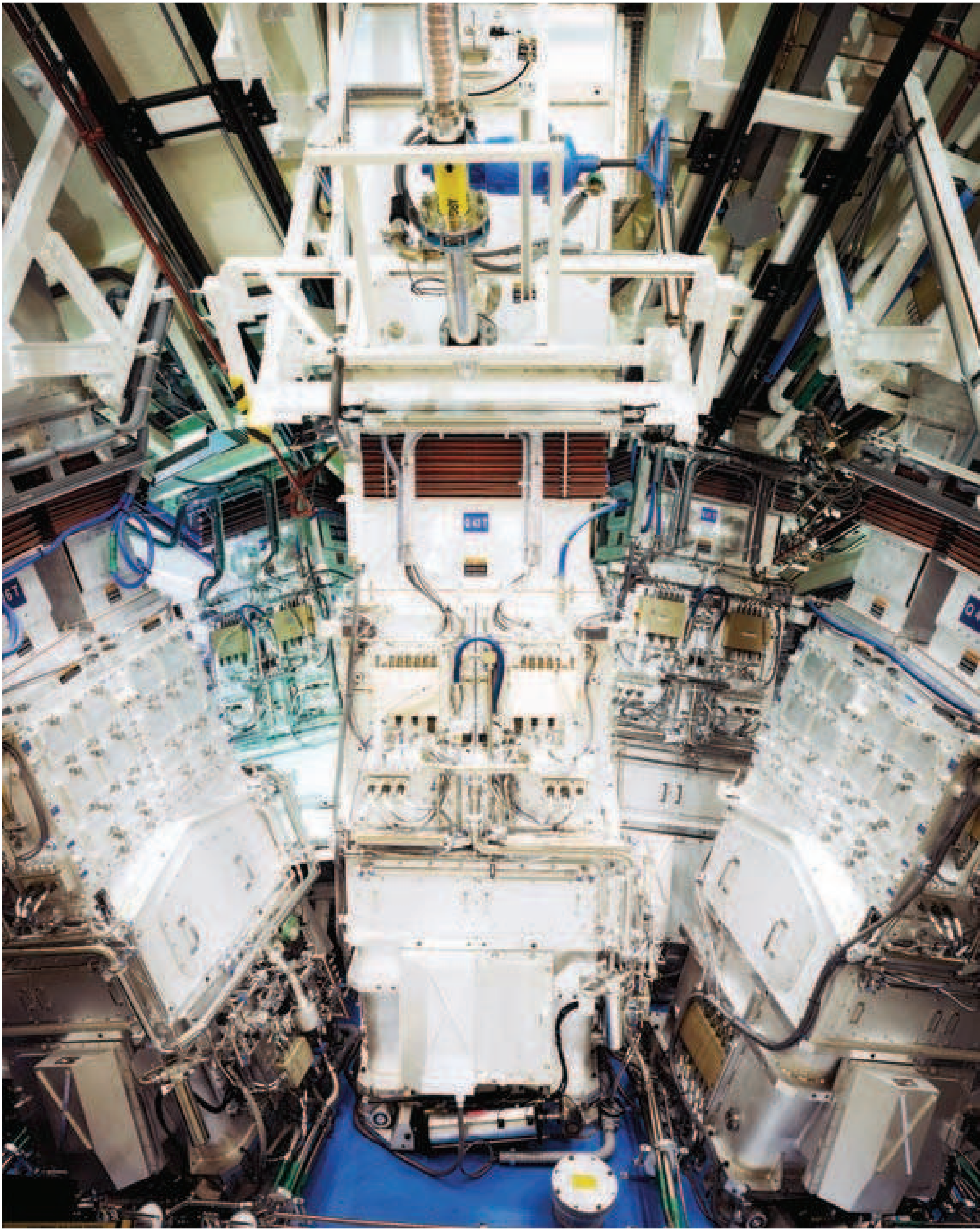
LASER BAY TWO The laser beams reach peak energy levels after being amplified 15,000 times in two vast rooms, one of which is pictured opposite. Above: An optical switch causes the beams to travel through the same amplifier four times before being released to the target. In place of conventional electrodes, which would be vaporized by the beams, the switch uses a plasma (purple) to convey electrical charge. Right: To make the 3,072 one-meter-long neodymium-doped glass slabs required by the main amplifiers, researchers had to invent new, faster manufacturing methods.

a professor of nuclear science and engineering at MIT, will be "an incredibly impressive technological achievement."

On the same afternoon when technicians worked to install the target-alignment sensor, others have started to gather in the facility's control room, with its large screens and clusters of workstations. They're preparing for a test shot of the laser, minus the fusion pellet; as a safety precaution, it's been scheduled for night, after the facility's laser bays and target chamber have been cleared of workers.

Firing the laser requires setting 60,000 different control points. The sequence of events that delivers the laser pulse to the target is too complex for human control, Van Wonterghem says, so after the settings are selected, a network of 1,500 computers will take over and carry out the final countdown, with the researchers' hands hovering near the many emergency-shutdown buttons arranged throughout the room.

If it all works, the lasers will deliver a pulse of power 500 times greater than the peak electricity-generating capacity of the United States. The pulse will ignite the thermonuclear explosion—essentially creating a tiny star.



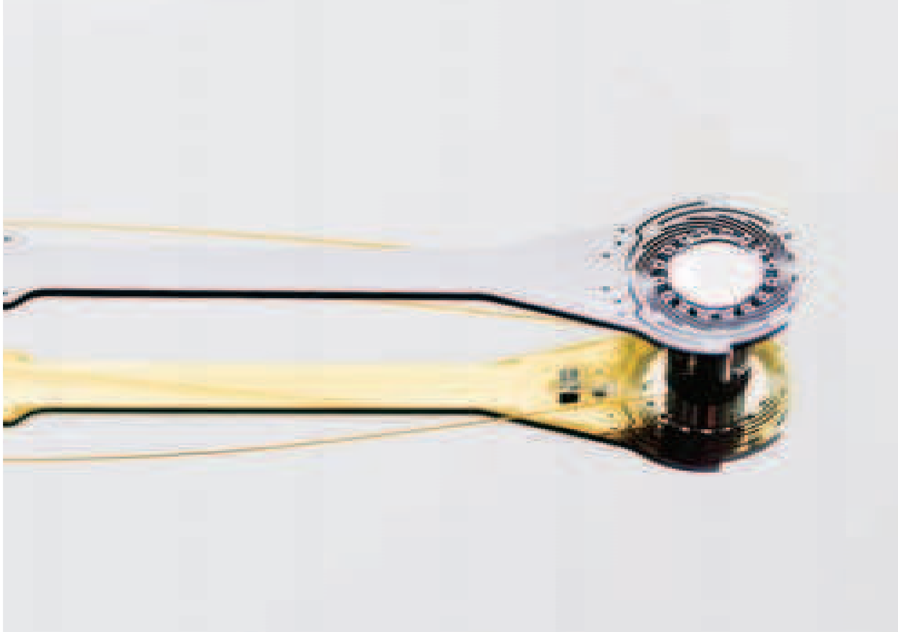
POWERING UP

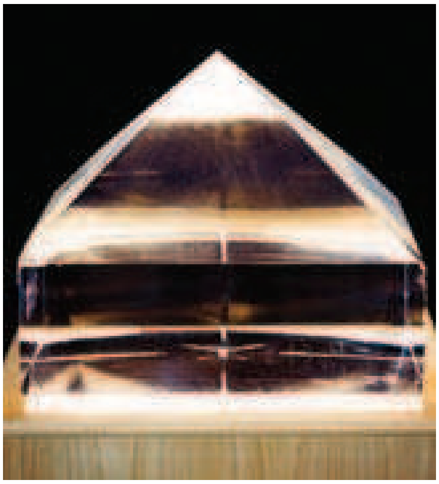
Significant hurdles will remain before such a process can be used to generate electricity. The fusion reactions are expected to produce 10 to 20 times the amount of energy delivered by the lasers. But this does not take into account the energy needed to make the lasers in the first place: converting electricity into laser light is an inefficient process. Making up for the wasted energy, and producing enough extra to generate electricity, would require fusion reactions that generate about 100 times the energy delivered by the lasers.

Speaking in a cluttered office near NIF, Moses says there are at least two potential ways to get around this problem. One requires combining two laser pulses in a process called fast ignition. In theory, this could reduce the amount of laser energy needed to ignite a sustained reaction. NIF, however, isn't currently set up for this; it's an approach that will be taken by other laser fusion projects now under construction, and eventually by NIF as well.

The other approach, Moses says, is to combine fusion with fission, the reaction used in conventional nuclear power plants. This option doesn't offer the same prospect of nearly limitless energy as fusion alone, but it could increase by orders of magnitude the amount of energy that can be extracted from uranium, greatly enhancing this already abundant source of fuel. At the same time, it could remove the chief objection to nuclear fission by eliminating almost all the long-lived radioactive waste it typically produces. "Right now we only get half a percent to 1 percent of the available energy," Moses says. "We can get 99-plus out."

The researchers at NIF have developed a detailed conceptual plan for pairing fusion and fission. The reason nuclear reactors use only a fraction of the energy in uranium is that as reaction products accumulate, they eventually interfere with the chain reactions needed to keep generating power. Fusion can supply a stream of neutrons that can keep these reactions going, using up almost all the energy in the fuel.





THE BUSINESS END Aluminum ducts (opposite) each deliver four laser beams to the target chamber (blue, at bottom). They are equipped with access panels so the focusing optics can be removed for repair if they are damaged by the powerful lasers. Before the lasers enter the chamber, they pass through crystal plates, cut from one-meter pyramids like the one at left, that convert infrared light into ultraviolet light. The beams converge on a cylinder (above) equipped with heat sinks (long arms) and heating coils (wrapped around the cylinder) that are engineered to uniformly cool a two-millimeter sphere of hydrogen inside to about 20 K. The laser beams, focused from 40 centimeters to a point thinner than a hair, enter from both ends of the nine-millimeter-long cylinder and collide with its inside walls, generating x-rays that compress and ignite the fuel pellet.

To be sure, not everyone agrees that laser-based fusion power will work. And some skeptics question whether NIF in particular can achieve self-sustained fusion, saying that the facility cannot produce sufficiently high-energy laser pulses without either damaging the laser optics or losing the tight focus on the target needed to compress the fuel evenly. Even if the facility achieves sustained fusion, producing electricity in a power plant would require lasers that could ignite a new fuel pellet 10 to 15 times a second. The NIF lasers, which have to be cooled down between shots, can be fired at most once every two to four hours. "Even if NIF is as successful as hoped, they'll still be a very long way from being in a position to turn this into a practical energy source," Hutchinson says.

NIF has already seen some signs of success. Earlier this year, all 192 lasers were fired at once and reached energy levels that will be enough to ignite fusion. Still, earlier laser projects at Livermore were supposed to achieve fusion ignition and didn't. Although a lot has been learned since then, there's no guarantee it will work this time. The good news is that it won't be long until the researchers know: after a series of test shots, they hope for success within the next two years. "We're looking forward to hearing some results," Hutchinson says. TR

WWW Follow energy editor Kevin Bullis on a tour of the National Ignition Facility: **technologyreview.com/photoessay**

Search Me

INSIDE THE LAUNCH OF STEPHEN WOLFRAM'S NEW "COMPUTATIONAL KNOWLEDGE ENGINE."

By DAVID TALBOT

On the evening of April 27 a ferocious rain raked the windows beside Jamie Williams's cubicle as the physicist sat, exhausted, immersed in the minutiae of food science. On the computer screen before him were raw tables of information from the U.S. Department of Agriculture, containing data on 7,000 foods, from blackberries to beef. He and a four-person team were "curating" the data, readying it for a new kind of online search. He combed through the tabs that identified 150 properties (nutrients, calories, carbohydrates, and so on), making sure the various abbreviations were consistent and readable by computers. He organized foods into groupings to facilitate natural-language queries. A search for nutritional information on "milk" would provide an average value, for example, while "skim milk" would provide a specific answer.

Williams wasn't toiling in a redoubt of Silicon Valley Web entrepreneurs but in a midwestern citadel of science geeks: Wolfram Research, in Champaign, IL, housed in an office block overlooking a Walgreens and a McDonald's. This was the corporate lair of Stephen Wolfram, the physicist and maker of Mathematica, which is generally acknowledged to be the most complete technical and graphical software for mathematicians, scientists, and engineers. Williams was working on something his company was calling a "computational knowledge engine": Wolfram Alpha. In response to questions, Alpha was meant to compute answers rather than list Web pages. It would consist of three elements, honed by hand in Champaign: a constantly expanding collection of data sets, an elaborate calculator, and a natural-language interface for queries.

What might Wolfram's system do that Google can't? Say you wanted to know how much cholesterol and saturated fat lurked in a slab of your grandmother's cornbread. You'd transcribe its ingredients from her yellowed index card to an online query bar, and Alpha would run computations and produce a USDA-style nutrition label. "Sure, you could go to Google, find out calories in a standard egg, and so on—but what a pain in the ass it would be!" exclaimed Wolfram Research cofounder Theodore Gray. "You'd need the data. And you'd need the data to be in forms that can be readily converted, if need be. And you'd need to add them up. You can do it, just as in earlier decades—you could go to the library to find a reference, and today you can go to Google or another search engine to get started. But we make it far easier." With a conventional search engine, he added, "enter 'one cup of sugar, one pound of flour,' and it completely throws up all over your screen."

Photographs by ROY RITCHIE

This is one example of the sort of thing Alpha was meant to do: provide deeper, more specific, and more graphically dressed-up answers to certain kinds of questions—though a limited set at first. Queries for "D# major" would produce graphics of the musical scale, queries for "Venus" would produce detailed, current maps of the night sky; queries on pairs of companies would produce comparative charts and graphs. It would add extra information: a search for "New York London distance" would produce the answer in miles, kilometers, and nautical miles; a map showing the flight path; and a comparison of how long it would take a jet, a sound wave, and a light beam to make the trip. Ask it about a

ALPHA MALE Fresh from his self-described reinvention of science, Stephen Wolfram hopes to circumvent Web search by computing answers to users' online queries—all from his company's databases. He launched his "knowledge engine," Wolfram Alpha, at his Illinois control center on May 15.

word (prefaced by the word *word*), and it would generate etymology tables and synonym networks. To do these sorts of things, it would start with math and science data sets and formulas already held in Mathematica, and build from there. Some of the new information, such as government data on food, would just need minor reorganization. That's what Williams was doing. Other kinds, such as real-time stock data, required licensing. Still others, such as

data on aircraft, would be gathered from open Web sources such as Wikipedia and Freebase, and cleaned up—*curated*.

Wolfram himself was in Boston, preparing to give the first public demonstration the next afternoon. (He'd already done demos for Tim Berners-Lee, inventor of the World Wide Web, and several technology-industry captains, including Microsoft's Bill Gates, Google's Sergey Brin, and Amazon's Jeff Bezos.) I sat in Gray's office, which seemed more like a shrine to the periodic table of the elements than a workplace: samples of nickel, chromium, selenium, sulfur, and dozens more adorned glass shelves. (He proudly opened a lead box and retrieved a dull metallic slab, about the size of two packs of cards. It was 11 pounds of uranium—not enriched, thankfully, but still mildly radioactive.) "It's a limited notion that the only thing you can do with search today is basically a textual search of existing printed material," Gray said. "That represents a huge failure of imagination."

IT'S ELEMENTAL Wolfram Alpha may initially have limited scope, a sometimes rigid user interface, and vague source information, but company cofounder (and element collector) Theodore Gray says the leading search engines are afflicted by "a huge failure of imagination" and are bad at math.

Down the hall, Eric Weisstein, an astronomer and creator of MathWorld, the online reference now hosted by Wolfram, sat in an office amid spider-plant cuttings in wax-paper cups (they are especially efficient at purifying air, he explained), putting the finishing touches on a comprehensive unit converter to drive some of Alpha's results. "If you search the Web, there are hundreds, if not thousands, of sites where people can convert feet to meters," Weisstein said. "But they are not flexible enough, authoritative enough, and in most cases they don't have enough coverage." Such calculators can't tell you how many grams are in a cup of milk or a cup of flour (the answer varies by substance). And forget about using them to convert a "pinch" (380 milligrams, in the case of salt) or a "drop" (if it's corn oil, one "metric drop" is 56 milligrams), or a "hogshead" (quite a lot of wine: 248 kilograms), much less units of thermal conductivity, international men's hat sizes, or any kind of bushel. "Bushel is an important one. A bushel of soybeans is not the same as a bushel of wheat, is not the same as a bushel of volume, ain't the same as a bushel of mass," Weisstein said. "We've gone and built the world's best unit converter!"

Throughout the building, and in remote locations, about 150 Wolfram staffers labored in similar fashion—some in pretty far-out fields. I found Ed Pegg in his cubicle, immersed in the subject of tiling. At his fingertips was the definitive reference, the 700-page *Tilings and Patterns* by Grünbaum and Shephard, describing everything from obscure crystallographic patterns in materials to the herringbones and basket weaves of brick walkways. There were so many variations: Islamic tiling patterns (octagons, hexagons, and two types of stars); double spirals made of nine-sided nested wedges; 14 kinds of patterns based on various pentagons. Although the tiling corpus would not be loaded by launch time, Pegg was creating ways for patterns to be combined and calculated. With these and other tools, a textile designer might create an Escher-like pattern (using interconnecting flowers, say, instead of lizards); a chemist might explore how a collection of molecules could fit together; a homeowner might generate a pattern for a new bathroom floor.

But first, Alpha had to launch—and the launch date was just three weeks off. Much remained unclear. Would the natural-language interface work well enough? Would the two supercomputers (which had just arrived at the data center outside of town) bear up on launch day—or would the site crash, as Cuil, the putative Google killer of 2008, had done? And would people really care to learn how many milliseconds it takes a light beam to go from New York to London? In Champaign, the developers were just trying to stamp out glitches. "There is a bit of a daunting feeling of knowing this never ends," Williams confided, "even though this is launching."

Gray stopped by Williams's cubicle. The two men huddled over the computer screen, silent for a moment.

"Why won't it work with two cups of flour and two eggs?" Gray asked, finally.

"Well," Williams replied, "there's a bug."

SLOW SEMANTICS

In 1993 a newly minted University of Maryland graduate, a brainy Russian with an interest in computers, interned at Wolfram Research. He did some hands-on work on Mathematica's kernel, or the core of the software. Then he went off to get his master's degree at Stanford—and to cofound Google. Today Google handles 64 percent of all searches made by Americans, but the erstwhile Wolfram intern, Sergey Brin, is not entirely happy. He dominates

> “We’ve bitten the bullet and said, ‘Let’s curate all this data ourselves!’” Wolfram says. “It would be great if the Semantic Web had happened and we could just go and pick up data and it would all fit beautifully together. It hasn’t happened.”

an industry, he’s worth $12 billion, and he hobnobs at the World Economic Forum’s annual meeting in Davos, Switzerland. Search technology, however, hasn’t kept pace with his personal rise. “[T]here are important areas in which I wish we had made more progress,” Brin wrote in Google’s 2008 annual report. “Perfect search requires human-level artificial intelligence, which many of us believe is still quite distant. However, I think it will soon be possible to have a search engine that ‘understands’ more of the queries and documents than we do today. Others claim to have accomplished this, and Google’s systems have more smarts behind the curtains than may be apparent from the outside, but the field as a whole is still shy of where I would have expected it to be.”

Among all the leaders in Web search over the years—from Excite (went bankrupt) to Alta Vista (absorbed by Yahoo in 2003) to today’s top five players (Google, Yahoo, Microsoft, Ask, and AOL)—the core approach has remained the same. They create massive indexes of the Web—that is, their software continually “crawls” the Web, collecting phrases, keywords, titles, and links on billions of pages in order to find the best matches to search queries. Google triumphed because its method of ranking pages, based partly on analyzing the linking structure between them, produced superior results. But while the Web has expanded 10,000-fold over the past decade, search engines haven’t made comparable progress in their ability to find specific answers and then put them together intelligently. The Semantic Web—the long-envisioned system in which information is tagged to allow such processing—is still a long way off.

Last year Yahoo launched something called SearchMonkey, which allows Web-page publishers to improve search returns by adding tags telling the search engine’s software, “This is an address,” “This is a phone number,” and so on. (So now, if you search on Yahoo for a restaurant, you may receive, beyond a link to the restaurant’s page, bullets listing the restaurant’s address, its phone number, and a compilation of reviews.) “What SearchMonkey is doing is taking the promise of the Semantic Web and putting it out in the open so publishers can participate,” says Prabhakar Raghavan, head of Yahoo Labs. Google recently began doing something similar, called “rich snippets.”

But such ideas have been slow to spread across the Web, even though the World Wide Web Consortium (W3C), the international standard-setting body led by Berners-Lee, has set out specifications to help implement them more broadly. And even if the W3C standards were broadly applied, they do not offer much guidance on computation, says Ivan Herman, who heads the W3C’s semantic efforts from Amsterdam: “How this data is combined with numerical calculation and math processes is not well defined, and that is certainly an area in which we have to work.”

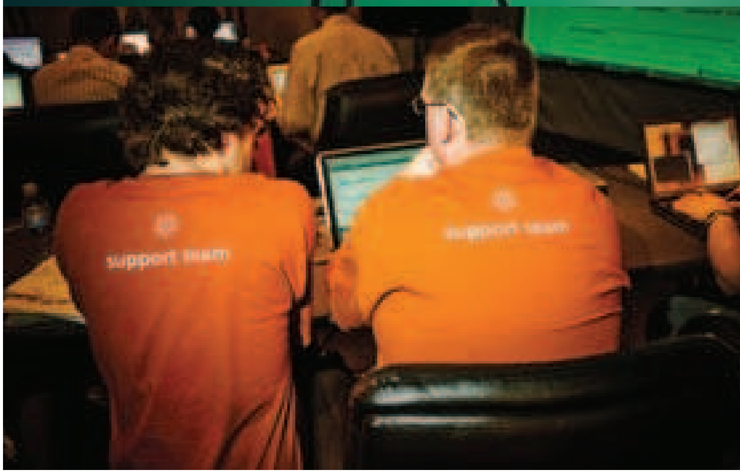
So while today’s search engines are increasingly broad and useful—expanding into new categories (maps, photographs, videos, news), learning to answer simple questions (“What is the population of New York?”), and even doing basic conversions (“What is 10 pounds in kilograms?”)—they aren’t particularly deep or insightful. “While Google is great,” says Daniel Weld, a computer scientist at the University of Washington and a Semantic Web researcher, “personally I would rather have the ship’s computer on the Starship *Enterprise*, where you ask high-level questions and it gives the answer, and explains the answer, and then you can say, ‘Why did you think that was true?’ and it takes you back to the source.”

As Stephen Wolfram sees it, he’s providing the infrastructure for answering questions in truly intelligent ways—albeit on subjects biased initially toward geeky domains. “We don’t have the problem of dealing with the vicissitudes of the stuff that’s just sort of out there on the Web,” he says. “We’ve bitten the bullet and said, ‘Let’s curate all this data ourselves!’ It would be great if the Semantic Web had happened and we could just go and pick up data and it would all fit beautifully together. It hasn’t happened.”

THE DEMO

At 3 P.M. on April 28, launch was still two weeks out as the 49-year-old Wolfram—graying, balding, and full of nervous energy—took his place at a Harvard Law School lectern, clad as usual in an oxford shirt, khakis, and Nike sneakers, to deliver the first public (and webcast) demonstration of Wolfram Alpha. Speaking in his soft English accent, he ran through some of the engine’s bag of tricks, such as entering strings of Gs, Cs, As, and Ts to obtain detailed data about the genes in which a DNA sequence appeared.

Over the previous two decades, Wolfram had come to be known for both his brilliance and his self-aggrandizement. A London-born prodigy, he skipped an undergraduate degree to receive his PhD in physics from Caltech when he was 20, and won a MacArthur Foundation “genius” grant two years later. He held a series of prestigious posts at Caltech, the Institute for Advanced Study at Princeton, and the University of Illinois. But in the mid-1980s he left academia to found Wolfram Research, and in 1988 the company issued the first version of Mathematica. The software contains vast libraries of mathematical functions, tools for visualizing data in two and three dimensions, and deep data-



bases on astronomical bodies, chemical compounds, subatomic particles, socioeconomic matters, financial instruments, human genes and proteins, and some simple biographical information, among other things. And it produces wonderful visualizations: geometric shapes, molecular diagrams, orbit plots.

Fourteen years after the first release of Mathematica—a period during which he published no research—Wolfram birthed a 1,200-page tome, *A New Kind of Science*, which he thereafter referred to as *NKS*. In it, he posited that many complex systems and problems—from plant and animal morphologies to quantum mechanics—could be reduced to simple rules. In the *New York Times*, George Johnson proclaimed, "No one has contributed more seminally to this new way of thinking about the world." But Wolfram's own characterization—that the book "has been seen as initiating a paradigm shift of historic importance in science"—met with more than a little eye rolling. "The adjective *Wolframian* has entered the lexicon, to mean taking something that everyone knows and presenting it as this astounding discovery about the nature of reality," says Scott Aaronson, a computer scientist at MIT (whose blog, Shtetl Optimized, is published on technologyreview.com). Aaronson does not deny that Mathematica is "very cool software," but he says that *NKS*, while it has value as popular science, "has essentially had zero impact on the areas of computer science and physics that I know about."

To Wolfram, Alpha now joins *NKS* as one of the great scientific endeavors in human history. He distributed a two-page list placing it at the end of a continuum that begins with the invention of arithmetic and written language and goes on to mention the Library of Alexandria, Isaac Newton, and the creation of the *Encyclopedia Britannica*. He positions Mathematica just before the invention of the World Wide Web in 1989; *NKS* earns a spot between Wikipedia and Web 2.0. He describes the final entry, Wolfram Alpha, as "defining a new kind of knowledge-based computing."

A real-world validation of Alpha's potential importance came partway into Wolfram's Harvard Law talk. At 3:17 P.M., Google's official blog announced a new service allowing people to search and compare public data, starting with federal census and labor data. The service would return not Web pages but Google-produced charts and graphs. (A search for "Ohio unemployment rate," for example, would produce a chart of the data, plus ways to compare that rate to those of other states.) The blog post called it a way to start tapping vast realms of "interesting public data" on "prices of cookies, CO_2 emissions, asthma frequency, high school graduation rates, bakers' salaries, number of wildfires, and the list goes on."

KNOWLEDGE WORKERS Staffers near Champaign, IL, man the control center during Alpha's launch in May (at bottom right, Stephen Wolfram displays a mobile interface). Although users' queries often elicited the reply *Wolfram Alpha isn't sure what to do with your input,* the site's strong graphical presentation of numerical data highlighted an important but elusive goal of Web search.

Google had been working on the service for two years, since acquiring Trendalyzer, on whose technology the graphics are based; the company says the announcement's timing was a coincidence. But clearly, the industry giant was acknowledging the same sort of deficit in Web search that Wolfram's people were attacking.

Two weeks later—on the eve of the Wolfram launch—Google threw an event dubbed "Searchology," at which it announced another new data-crunching service, Google Squared. The technology, now available on its Google Labs site, combines information from different Web sources and packages it into nice tables. A search for "roller coasters," for example, produces a table of American amusement-park rides from Excalibur to Montezooma's Revenge. Columns provide thumbnail photos, descriptions, heights, and lengths. Users can click on the results to delete errors in the original table and refine the search. Marissa Mayer, a Google vice president, said during the event that Google Squared "pushes search in an entirely new direction." She added, "It is a hard computer science problem—to take this unstructured information and present it in a structured way."

Google also said it would provide better real-time data in search results. If you search for "earthquakes San Francisco," Google, like Alpha, will now push out the latest relevant reports from the U.S. Geological Survey. (It is doing something similar with real-time data on airline flights and sports scores.) Peter Norvig, Google's research director, told me that the technologies represent a foretaste of the company's efforts in finding, combining, and presenting numerical data. "I would say in general, our approach would be more toward open systems rather than closed, curated ones," Norvig said, "but I do appreciate the broad kind of user interface [Wolfram Alpha is] providing, and the data analysis tools. We would like to do more of that. Maybe having him out there will push us to release more, faster—I don't know." Scott Kim, executive vice president for technology at the search engine Ask, was more direct in suggesting that Wolfram would have an influence. "I think it opens people's eyes—the general public's eyes—to what you can get out of a computational engine, and how that can be integrated into a search engine," he said of Alpha. "This is absolutely part of the future of search, and there is a long way to go."

> "There is always one guy out there who has an arcane question to ask," says Prabhakar Raghavan, who leads Yahoo's search strategy, "but we have to maniacally focus on satisfying 99 percent of the population really well."

LAUNCH

Ever the showman, Stephen Wolfram made sure the two supercomputers were dramatically lit with blue and green LED lights. In the new data center near Champaign, he'd set up a slightly elevated command post for himself. He'd arranged for the event to be webcast. And at 10:30 P.M. on May 15, as a tornado watch covered much of Illinois, he mouse-clicked a tab labeled "Activate," and a wall-mounted screen showed computer clusters blinking to life. "Statistically speaking, there will be some issues, and it's only a question of what issues they are," he said that night. But despite voltage fluctuations and earlier overloads on the supercomputers, Wolfram avoided a crash of the sort that bedeviled Cuil.

His engine itself still faced a big performance problem, however. As complete and elegant as it was when it knew something, there was much it did not know (and it was hard to guess what it might know). *Wolfram Alpha isn't sure what to do with your input* was a frequent response from the site. This was mainly because of the huge gaps in its curated data; Alpha is a library whose shelves are only partly filled. It is largely blind to history, politics, literature, sports, social sciences, and pop culture. The site was also bedeviled by an inflexible natural-language interface. For example, if you searched for "Isaac Newton birth," you got Newton's birth date (December 25, 1642; you also learned that the moon was in the waxing-crescent phase that day). But if you searched for "Isaac Newton born," Alpha choked. Aaronson tested it with me and found it couldn't answer "Who invented the Web?" and didn't know state-level GDP figures, only national ones. But it could ace all sorts of math questions, including a request for the surface area of the earth. Aaronson asked it, "What is the GDP of Ireland divided by the cosine of 42?" and received a chart reflecting the relevant calculations for GDP figures from 1970 to 2007, presented on a logarithmic scale.

Finally, there was a documentation problem. Clicking links revealed a variety of sources: the CIA's World Factbook, the website Today in Science History, the U.S. Geological Survey, Dow Jones, and the Catalogue of Life, an internationally maintained index of the world's known species. But nothing specified which source had provided which fact. (Gray says the company is working on adding such labels to specific facts and to computed results.)

But if you gave Wolfram Alpha every allowance—that is, if you asked it about subjects it knew, used search terms it understood, and didn't care to know the primary source—it was detailed, intelligent, and graphically stunning. Searches for materials gave you diagrams of chemical compounds; searches on astronomy gave you maps of the night sky (geolocated on the basis of your computer's IP address). It could do things the average person might want (such as generating customized nutrition labels) as well as things only geeks would care about (such as generating truth tables for Boolean algebraic equations). "Wolfram Alpha is an important advance in search technology in that it raises expectations about how content that is stored in databases should be searched," Marti Hearst, a computer scientist at the University of California, Berkeley, and the author of *Search User Interfaces*, told me. But she added that it "has a long way to go before achieving its ambitious goals."

Some of these problems will be addressed by adding more data, an effort Wolfram says will continue indefinitely. To help the process, the site includes links for people to submit individual facts, entire structured data sets, and even algorithms and models. Unlike Wikipedia—where the process of adding and editing information is free and open, with checks and balances provided by the community—Wolfram Alpha plans to maintain a more centralized form of control, saying that its "staff of expert curators" will check the data before adding anything to the corpus. But some believe that expansion will be difficult without some automated or community-driven process, and without indexing the Web as search engines do. "At a certain point, calculation isn't so useful if there isn't the raw data to drive it," says Weld of the University of Washington. "Google Squared is more the trend that I think will win this race."

Indeed, even granting that his engine is only a start, some skeptics doubt that Wolfram's approach will work for more than niche applications. "Although I have graduated as a mathematician and have a huge respect for anything mathematical, I am not sure you can handle all of the miseries of this world by mathematical formula and computation," says the W3C's Ivan Herman. Norvig echoed this objection. "There are certain data sets for which that [approach] is appropriate. If you are talking about atomic weight of gold—if different labs are off on that, they are off to the fifth or sixth decimal place, who cares?" Norvig says. "But many other things, there is no consensus. It depends what the data is. It depends what type of calculation you want to do. And if it's non-numeric data, then it's less clear what sort of calculation you can do." And Weld piled on: "Imagine a question like 'Who are the most dangerous terrorists?' That's a real hard one. Is someone a terrorist? How do

WWW Watch Wolfram explain the vision behind his "computational knowledge engine": **technologyreview.com/wolframalpha**

CAKEWALK On questions it can handle—especially computable ones in math, science, and engineering—Wolfram Alpha performs many original tricks. Presented with pancake ingredients (1), the engine offers possible variations (2), shows how it interpreted the input (3), and produces a combined nutrition label (4). Behind the scenes, Wolfram's Mathematica software first performs any needed unit conversions (for example, converting "pinch of salt" to a computation-ready "380 milligrams of salt"). But an offer of "source information" (5) doesn't trace facts to specific references.

we assess danger? And danger to whom? It is computationally very difficult to do that kind of reasoning."

Still, in some cases Wolfram's obsession with computation could serve certain users better than do the market-share-obsessed major search companies, who are, quite naturally, most interested in helping the masses get better results on queries they are already performing. "Let's say that reviews of a particular hotel are scattered around several sites," says Yahoo's Raghavan. "Giving a summary rating is much more in line with what users tend to ask, rather than saying they want the combined populations of the Balkan countries in Eastern Europe. There is always one guy out there who has an arcane question to ask, but we have to maniacally focus on satisfying 99 percent of the population really well."

In its first two weeks, Wolfram Alpha processed 100 million queries and received 55,000 pieces of feedback, suggesting more than a niche level of interest in deeper answers. "What Wolfram Alpha will do," Wolfram says, "is let people make use of the achievements of science and engineering on an everyday basis, much as the Web and search engines have let billions of people become reference librarians, so to speak." A Firefox add-on has already surfaced, allowing searchers to display Alpha results alongside Google results. And Wolfram says the engine will undergo continual improvement. Three weeks after launch he announced the first broad update to its code and data, including enhancements to the natural-language interface, more data on subcountry regions (such as Wales), a new ability to search for a stock price on a specific date, and "more mountains added, especially in Australia."

Wolfram says he has invested "tens of millions" of dollars in Wolfram Alpha, atop "hundreds of millions" spent developing Mathematica over two decades. Advertising has started appearing alongside results, and he plans to offer a professional subscription version with more features. A programming interface (called an API) allows developers to build applications that can make Wolfram Alpha searches. "We'll see if this is an exercise in philanthropy or a thriving business," he told me.

Even Aaronson allows that the real judges will be the people. "Millions of people will try it, and either it will be useful or it won't—and that's the real test," he says. "It's not some abstruse claim about the nature of reality. It's here as a useful service, and the test is, do people find it useful or not?" TR

DAVID TALBOT IS *TECHNOLOGY REVIEW*'S CHIEF CORRESPONDENT.

Medicine's New Toolbox

AN ALTERNATIVE WAY TO MAKE STEM CELLS COULD OPEN A WINDOW ON HUMAN DISEASE.

By LAUREN GRAVITZ

On the second floor of a building in one of South San Francisco's numerous business parks, a new biotech company has set up shop. The walls sport a fresh coat of white paint, and the bench tops are shiny and bare. The tile floors are still glossy, and an expensive new cell-sorting machine sits, untouched, on the loading dock downstairs.

The building's new inhabitant, iZumi Bio, is pursuing a technology as new and full of promise as the lab itself—a technology that's moving faster than the company can fill its empty space. It revolves around induced pluripotent stem (iPS) cells: adult cells genetically reprogrammed to act like embryonic stem cells, which can turn into just about any type of cell in the human body.

Scientists have been talking about the medical promise of stem cells for more than a decade, even before human embryonic stem cells were successfully isolated in 1998. Most of the public attention has focused on their regenerative power: since stem cells can renew themselves and differentiate into specialized cell types, they could potentially be used to build replacement organs, heal spinal-cord injuries, or repair damaged brain tissue. But the research world has also pursued another, even broader-reaching goal: using the cells of patients with various illnesses to derive pluripotent stem cells, which can give rise not just to the specialized cells in a particular organ or tissue but to virtually any cell type. Those cells could be used to create laboratory models of disease. For example, a cell from a Parkinson's patient could be turned into a neuron, which would exhibit the progressive molecular changes at work in the neurodegenerative disorder. This type of tool could capture the details of human disease with unprecedented accuracy, and it could revolutionize the way researchers search for new treatments.

Studying human disease in the lab is an enormously challenging task. It's difficult to obtain brain tissue from a living Alzheimer's patient, for example, and impossible to study how that tissue changes as the disease progresses. Animal models can offer only rough approximations of a human illness, capturing at best a few of its symptoms or causes. But iPS cells could yield a much more comprehensive picture. Because each cell line comes from a human patient, the cells reflect the complex array of factors that led to the patient's disease: the genetic mutations, the effects of environmental history. And because those cells can be prodded to develop into a variety of tissue types, scientists can watch the disease unfold in a petri dish. They can observe, for example, the subtle molecular changes that take place in the neurons of a patient with Alzheimer's long before the telltale signs of the disease, such as amyloid plaques, can be seen in the brain. It's the difference between trying to piece together the details of a plane crash from photos of the wreckage and watching a video of the crash from every angle, with the ability to stop, zoom in, and rewind at will.

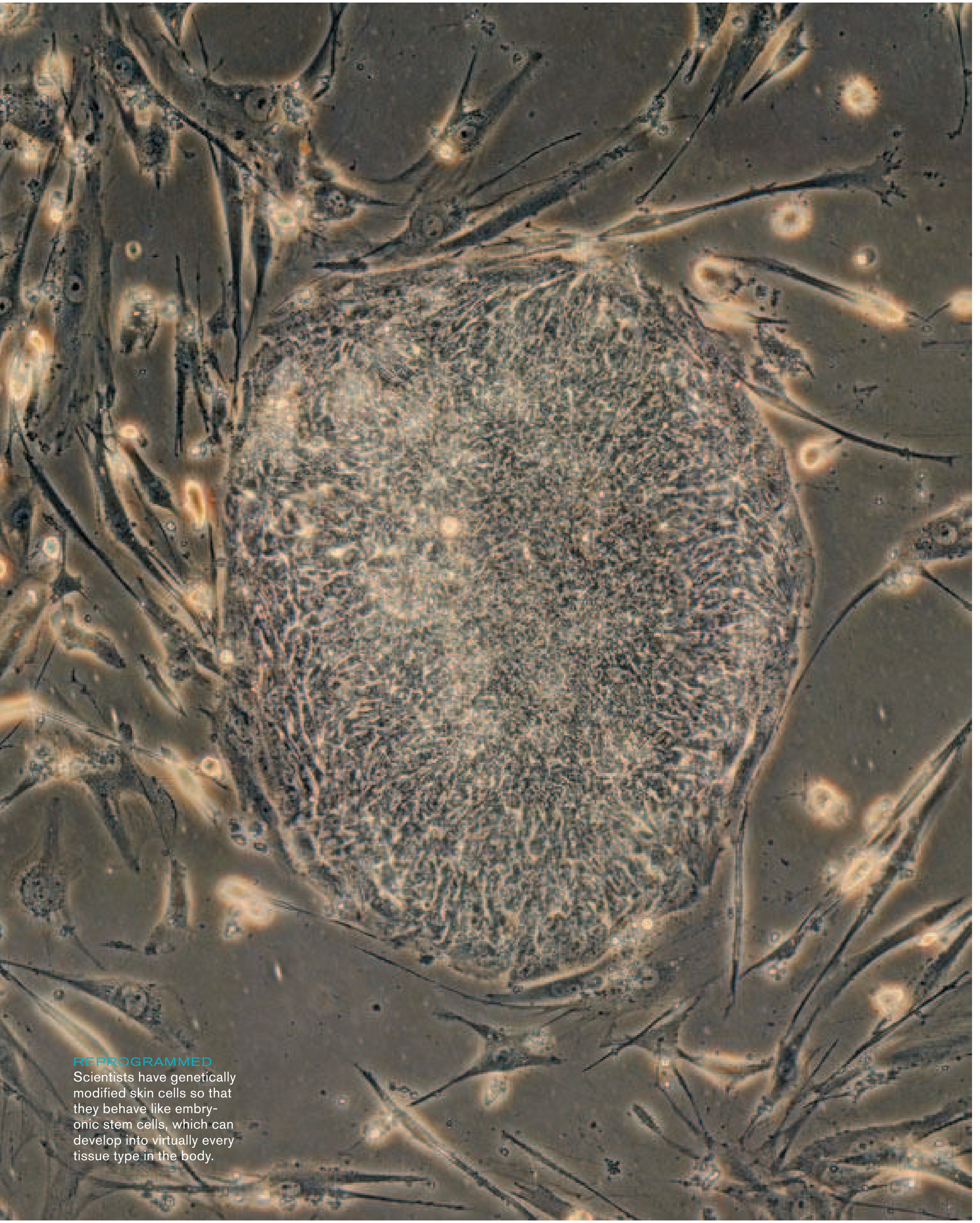
"The past two years have been nothing short of a revolution," says John Dimos, a senior scientist at iZumi. "These cells didn't really exist two years ago. This is all brand-new technology, and it's opening up the potential for brand-new science." The company plans to take advantage of that potential by developing a bank of iPS cells from patients with various diseases and using the cells to screen candidates for drug development.

Thousands of other labs are jumping at the chance to use iPS cells as well—whether to create new disease models, to study tissue development, or even to figure out how to build tissue for transplantation. Biologists say the field is charged with a kind of energy not seen since soon after the structure of DNA was discovered. "This is a really rare phenomenon in the biological research community," says Sheng Ding, a chemist at the Scripps Research Institute in La Jolla, CA. "It's a sensation, really. Everyone, more or less, is working on using iPS-cell technology for their specific research interest."

STEM CELLS 2.0

Scientists have been searching for ways to directly reprogram adult cells for decades. That hunt has been pushed forward by the desire to develop an alternative to human embryonic stem cells,

JUNYING YU/UNIVERSITY OF WISCONSIN-MADISON



REPROGRAMMED
Scientists have genetically modified skin cells so that they behave like embryonic stem cells, which can develop into virtually every tissue type in the body.

which are fraught with both technical and ethical issues. The cells are usually derived from four- or five-day-old embryos that would otherwise be discarded from in vitro fertilization clinics (although sometimes embryos have been created expressly for research purposes). Using this technique to create a robust cell line is tricky and highly inefficient. Not only are the embryos themselves hard to obtain, but the cells are delicate and difficult to grow.

Another technique, human therapeutic cloning, is even more controversial, and both technically and practically challenging. Scientists transfer the nucleus of an adult cell into the hollowed-out shell of an unfertilized egg cell—which can then develop into an embryo, yielding stem cells that are genetic clones of the adult cells. But the lack of human eggs for research has proved a huge hurdle, and scientists have yet to generate cloned human cell lines.

But three years ago Shinya Yamanaka, of Kyoto University in Japan, figured out how to return adult mouse cells to an embryonic-like state in a process that never involved an actual embryo. He found that using a virus to deliver genes for just four specific proteins to the nucleus of an adult cell could give it the ability to differentiate into a wide variety of cell types, just like the stem cells derived from embryos. Those proteins, typically found in developing embryos, appear to turn other genes on and off in a pattern characteristic of embryonic rather than adult cells. A year after Yamanaka's discovery, his group and two others reported that they could induce human cells to do the same thing.

As a physician and venture capitalist closely following stem-cell research, Beth Seidenberg saw the potential almost immediately. Seidenberg, a partner at Kleiner Perkins Caufield and Byers, teamed up with another venture capital firm, Highland Capital Partners, to found iZumi in 2007, funding the company with $20 million. After 20 years in pharmaceutical research, Seidenberg has had a lot of time to think about what the industry is doing right and where it's going wrong. She says, "I became really intrigued by the idea of starting with a patient who had a disease and working backwards, which is exactly the opposite of how we pursue new therapies for treatment of disease today."

To illustrate the role iPS cells could play in drug discovery, John Dimos points to amyotrophic lateral sclerosis (ALS), a neurodegenerative disease he has studied for years. About 2 percent of all cases have a known genetic cause—a mutation in a gene called *SOD1*. Nearly all the work in animal models has focused on this rare form of the disease, because researchers know how to use the gene to trigger it in mice. With the new technology, however, scientists can use a skin biopsy to generate pluripotent stem cells from any patient with ALS. The genetics and other possible factors underlying the disease are captured in the cells, even if no one knows explicitly what those factors are. The same holds true for Alzheimer's, diabetes, autism, heart disease, and myriad other conditions whose complex origins have proved difficult to identify.

As a postdoc at Harvard, Dimos built a cellular model of ALS, making it possible to study a neurodegenerative disease outside an animal for the first time. He and his colleagues collected skin cells from an 82-year-old woman with ALS, reprogrammed them into iPS cells, and directed the cells to differentiate into motor neurons that were genetically identical to the donor's defective cells. "It was the first paper to show that you can use a stem cell to see disease pathology in a petri dish," says Douglas Melton, codirector of the Harvard Stem Cell Institute. "That means you can now study diseases in petri dishes and not in people. That's huge."

Because they are derived from human patients with documented medical histories, iPS cells are accompanied by reams of previously inaccessible information. "You can see from their medical history the progression of the disease, how they responded to different drugs, exactly what symptoms they experienced, and when," says Dimos. Certain drugs may be more or less effective depending on a patient's genetic makeup; some people, for instance, respond well to the breast-cancer medication taxol, while others may have no response at all. If scientists knew that specific medications worked for certain people or, conversely, caused them to suffer severe side effects, they could use their cells to try to figure out why—and use that information to develop better therapies.

So far, Harvard Stem Cell Institute scientists and their colleagues have used iPS-cell technology to create more than 20 disease-specific stem-cell lines designed to help them study conditions including Parkinson's and type 1 diabetes. While the field is still in its early stages, researchers have begun to see evidence that they can replicate certain aspects of human disease in a dish.

The first goal for iZumi is to establish its own bank of reprogrammed cells. To start, the bank will be stocked with cells derived from patients with various neurodegenerative diseases—ALS, spinal muscular atrophy, and Parkinson's—as well as a cardiovascular disorder known as calcific aortic valve disease, which they're studying in conjunction with collaborators at the Gladstone Institute at the University of California, San Francisco. By creating complex systems of cells that incorporate the different cell types affected in each disease, such as motor neurons and skeletal muscle cells, they can watch precisely how ALS and the other conditions develop.

The company wants to develop drugs, focusing on therapies for neurodegenerative diseases. It will also work with other pharmaceutical companies to find treatments for other diseases. "We believe that we'll have our own proprietary therapeutics in development in the fifth year—by 2012," says CEO John Walker.

A BUMPY ROAD

If iPS-cell scientists have learned anything from the saga of embryonic-stem-cell research, it's that potential doesn't always translate into profit or success: despite the vast promise of embryonic stem cells, building a business model around their thera-

OTHER iPS COMPANIES

Company	Strategy
Fate Therapeutics La Jolla, CA	Using iPS cells to search for drugs that trigger growth of adult stem cells
Cellular Dynamics Madison, WI	Turning iPS cells into colonies of heart, immune, kidney, and other cells for drug screening
GlaxoSmithKline Worldwide (HQ in the U.K.)	$25 million collaboration with the Harvard Stem Cell Institute

peutic use has been a challenge. Some of the blame can be laid on President George W. Bush. In 2001—citing ethical objections to the process used to obtain the cells, which destroys a days-old embryo—he restricted federal research funding for the technology to a small number of stem-cell lines already in existence. The controversy, the lack of federal investment, and some uncertainty surrounding the science itself made some researchers reluctant to study embryonic stem cells, and many venture capitalists were hesitant to back efforts to commercialize them.

Barack Obama ordered the limits on federal funding removed early in his presidency, but his predecessor's policies probably set the field back many years. And embryonic stem cells are so finicky and unpredictable that developing treatments based on them has been difficult even apart from the funding obstacles. Only this year, more than a decade after human embryonic stem cells were first isolated, will they finally make it into clinical trials. The first therapy, a treatment for acute spinal-cord injury developed by biotech startup Geron, is headed for trials later this year.

"It's kind of a 'good news, bad news' scenario," says Daniel Omstead, CEO of Hambrecht and Quist Capital Management. "Every quarter or year, you see new developments that make you very excited about the future but more circumspect about ... being able to make money in the near term for investment in technology that will cure disease." He's not yet sure whether iPS-cell technology will prove to be the stem-cell field's home run, and neither are his fellow venture capitalists. "I think many companies will come out of the stem-cell area, but I don't know that they'll be focused on iPS cells necessarily," says Amir Nashat of Polaris Venture Partners, which has funded a company partly based on the technology *(see table above)*.

Stem cells might be easier to commercialize as tools for drug development, an area in which the new technology seems especially promising. But iPS cells still hold many unknowns: they are not as well studied as embryonic stem cells, and there is not yet any standard by which they can be measured. That is one reason no one is yet willing to claim that iPS cells will make embryonic stem cells obsolete; indeed, the inconsistency of iPS cells is one of the biggest research hang-ups at the moment. Researchers don't quite understand why, but even cells from the same batch can behave very differently. Some are easy to turn into other tissues; some are stubborn. And the rapidly growing repertoire of methods for making iPS cells is adding to the variability.

Only a year ago, researchers had to use a virus to insert the four proteins required to turn an adult cell into an iPS cell. The virus also inserted little bits of itself into the cell's genome, an invasion that not only prevents therapeutic use but makes lab studies much less reliable. Newer methods use proteins or chemicals, while some techniques still use viruses. Before they can use the cells generated in all these different ways, scientists need to study and document their characteristics. "We just finished initial characterization of a group of 12 lines we made. And then we made some more," says Jeanne Loring, director of the Center of Regenerative Medicine at Scripps. "So we're suffering from the same thing everyone else is." In other words: "Oh my God, we have more lines than we know what to do with."

But Harvard's Melton, for one, thinks these problems are only temporary. "This is all solvable in the short term—in the next year or so," he says. After that, the trick will be figuring out how to prompt the cells to differentiate in the desired ways. There are more than 200 different kinds of cells in the body, and although iPS cells have the *potential* to turn into any of them, actually getting them to do so is a different story. "How do you tell a cell to become a pancreatic beta cell? How do you tell it to become a four-grain basal cell or a motor neuron?" he says. Scientists have already figured out how to make some neurons and blood cells, to name a few. But they cannot yet efficiently make such important types as pancreatic beta cells, the insulin producers that are destroyed in diabetes. Still, says Melton, "we're getting closer."

Though it seems a long way off, scientists still hold out the possibility that iPS-cell technology could one day be used for treatment. "The near-term value for iPS cells is in disease modeling, pathway identification, and drug screening and development," says George Daley, a stem-cell biologist at Harvard University and Children's Hospital in Boston. "But I don't give up hope that we will generate cells that will have therapeutic relevance."

For now, though, iZumi and other companies are focusing sharply on what they think will be the most immediate use of iPS cells: as tools for understanding some of our most devastating diseases and finding better ways to treat them. The new technology, they hope, will fundamentally change the repetitive, variations-on-a-theme approach to drug development that has hindered pharmaceutical progress in recent years. The discoveries it makes possible could one day transform medicine into something we're only just beginning to imagine. TR

LAUREN GRAVITZ IS A FREELANCE WRITER BASED IN LOS ANGELES, CA.

Chasing the Sun

THE FEDERAL GOVERNMENT IS ABOUT TO SPEND BILLIONS OF DOLLARS ON RENEWABLE ENERGY. IN PART II OF OUR SERIES ON THE FEDERAL STIMULUS BILL, WE LOOK AT THE IMPACT THE SPENDING WILL HAVE ON THE FUTURE OF SOLAR POWER.

By DAVID ROTMAN

The abandoned industrial site on the far edge of Chicago's South Side is an unlikely location for a large solar power plant. For one thing, Chicago is not a very sunny city. And the land itself, once a center of postwar manufacturing, has been vacant for 35 years and is now overgrown with trees and bushes, surrounded by a gritty neighborhood of aging houses. But Exelon, one of the country's largest electric utilities, says that by the end of the year it hopes to turn a 39-acre lot into the nation's largest urban solar plant. If it succeeds, row after row of nearly 33,000 silicon solar panels built and installed by SunPower, a photovoltaics manufacturer based in San Jose, CA, will cover the lot to produce 10 megawatts of power—enough for about 1,200 to 1,500 homes.

But there is a big *if* in this scenario of urban transformation. It will happen only if Exelon receives the generous loan guarantees for renewable-energy projects promised in this year's federal stimulus bill—funds that in this case would cover 80 percent of the project's costs. Barely viable with the loan guarantees and a handful of other federal and state subsidies, the $60 million solar plant would not be possible without such government support. Speaking from the 48th-floor offices of Exelon, nearly 20 miles away in downtown Chicago, Thomas O'Neill, the utility's senior vice president for new business development, is blunt about the

This is the second of two articles by David Rotman on technology and the federal stimulus package. The first, "Can Technology Save the Economy?," appeared in the May/June 2009 issue (find it at technologyreview.com) and examined the economic consequences of the U.S. government's plans to spend $100 billion on technology.


CHRIS STRONG

FIELD OF DREAMS A sprawling vacant lot on the South Side of Chicago could be the site of the nation's largest urban solar plant. Exelon, a Chicago-based utility, wants to fill 39 acres of the former industrial site with state-of-the-art photovoltaic panels that would produce enough electricity for up to 1,500 homes. The cost: $60 million.

economics of the solar plant. "If we can't secure the loan guarantee, we can't go forward with the project," he says.

Even with the federal subsidies, says O'Neill, the solar plant won't offer the double-digit returns usually required by investors in large energy projects. It would cost $6 a watt to build, whereas wind and natural-gas plants cost roughly $2 a watt and $1 a watt, respectively. And its 10 megawatts will contribute an insignificant amount of electricity to Exelon's vast generation capacity of 36,000 megawatts. But, says O'Neill, the project is "tailor-made" for some of President Obama's goals in the stimulus package. It would create jobs (250 people would be needed to construct it), and it would demonstrate that solar power can be "brought to the Midwest and to the inner city."

The proposed plant in Chicago is just one of the many renewable-energy projects that could get built because of the federal stimulus bill passed in mid-February (see "*Can Technology Save the Economy?*" May/June 2009 and at technologyreview.com). The U.S. Department of Energy is still in the process of choosing the projects that will receive loans and deciding how other newly available subsidies will be spent. But the potential windfall is already jump-starting plans for wind farms in the Midwest, massive solar plants in the deserts of southwest Nevada and southeastern California, and geothermal power plants in the Northwest. According to a recent analysis by the Energy Information Administration, an independent agency within the DOE, the stimulus bill will increase the amount of generating capacity from renewable sources to 156 gigawatts in 2015, up from 114 gigawatts today; renewable capacity would increase only to 118 gigawatts without the legislation.

The EIA report also points to a troubling reality, however: this increased use of renewable energy will have only a slight long-term effect on carbon dioxide emissions (*see "Powering Up," p. 48*). Even 156 gigawatts would satisfy only a small fraction of U.S. energy needs. And as Secretary of Energy Steven Chu has frequently argued, existing renewable-energy technologies cannot provide the large amounts of cost-competitive energy required to significantly reduce the country's reliance on greenhouse-gas-emitting fossil fuels.

SUN WORSHIP Brightsource Energy is testing solar thermal technology in a desert 60 kilometers outside of Jerusalem, Israel. The test plant, which produces four to six megawatts, uses 1,600 glass mirrors to concentrate the sun's energy on a central 60-meter-high tower, on top of which is a boiler. A commercial plant planned for California's Mojave Desert will be a hundred times larger, producing 400 megawatts.

The DOE has begun a massive infusion of funding into research on new renewable technologies. This spring the department announced $777 million over five years to support 46 new energy research centers.

Under Chu's leadership, the DOE has begun a massive infusion of funding into research on new renewable technologies. This spring the department announced $777 million over five years to support 46 new energy research centers, another $280 million for eight "energy innovation hubs," and $400 million to launch and fund the Advanced Research Projects Agency–Energy, a program based on the 1960s-era ARPA program that led to, among other things, the Internet.

Both the research funding and the subsidies aimed at existing technologies could be particularly critical for the solar industry. A number of physicists and chemists argue that finding more efficient ways to use the sun's energy offers the only feasible long-term option for replacing fossil fuels and significantly decreasing production of greenhouse gases. "We're bathed in these quantum particles that rain down on us from the sun, each of them carrying about two electron-volts of energy," says Paul Alivisatos, interim director of the Lawrence Berkeley Laboratory and head of its solar research center. "That's where the energy is." But solar power now accounts for a fraction of 1 percent of the total U.S. electricity capacity of 1,000 gigawatts. The main reason is cost.

Silicon cells like the ones Exelon would use, which are made from the type of high-grade silicon used in computer chips, represent the vast majority of installed photovoltaic capacity but are still about five times too expensive to compete with conventional sources of electricity. Newer types of solar cells that replace single-crystal silicon with thin films of semiconducting materials could be cheaper to make but are less efficient. Concentrated solar thermal power, in which large arrays of mirrors are used to collect sunlight and create steam that drives turbines, could come closer to fossil fuels in cost, but the facilities are expensive to build and require large areas of land in extremely sunny spots. In fact, no existing solar technology is currently competitive without help from government subsidies. That means the fate of solar power is especially vulnerable to the vagaries of government policy and the choices of those who make it.

THE SUN KING

Arnold Goldman knows how profoundly state and federal energy decisions affect the solar-power industry. In the early 1980s, his company, Luz International, built nine large solar thermal plants, with a combined capacity of 354 megawatts, in the middle of California's Mojave Desert. At the time, the Luz facilities supplied 90 percent of the world's solar-generated electricity. The technology they used was based on an ingenious design in which hundreds of thousands of mirrors, spread out over the ground, concentrate sunlight on a network of overhead tubes containing a synthetic oil; the hot oil heats water to create steam that then drives turbines to generate electricity.

COURTESY OF BRIGHTSOURCE

The solar facilities, the first of which came online in 1984, were economically possible because of generous incentives from both the federal and state governments. In 1979, President Carter had set a goal that 20 percent of U.S. electricity should come from renewable energy by 2000 (today the figure is still only about 2 percent). Carter and Congress passed hefty tax credits for investors in renewable-energy projects, and a federal law called the Public Utility Regulatory Policies Act, passed in 1978, offered further incentives to producers of alternative energy.

Then, in late 1990 and early 1991, it all collapsed, recalls Goldman. The tax credits put in place by the Carter administration had "deteriorated" during the presidency of Ronald Reagan, he says. But the final blow came from a seemingly esoteric change to California's tax code. The state had exempted renewable-energy facilities from paying property taxes, and because Luz's largest facilities were valued at more than $1 billion apiece, that exemption was worth as much as $20 million to $30 million per plant. Toward the end of 1990, California's governor vetoed an extension of the property-tax exemption. But a new governor was taking office in January, and Luz, which was spending $20 million a month to build its 10th plant, gambled that he would quickly reverse the action. When the new governor didn't immediately reinstate the tax exemption, Luz lost its bet. "We miscalculated," says Goldman. "We ran out of money and closed down operations."

With the California and federal governments again offering hefty incentives for renewable energy, Goldman is back, this time with even grander ambitions. In 2006 he founded Brightsource Energy in Oakland, CA; having raised $160 million in venture capital and corporate investments, it now plans to build a series of power plants with a combined capacity of more than four gigawatts. It will use a newer version of the Luz technology that achieves far higher temperatures; and instead of heating a network of oil-filled tubes, it uses tens of thousands of mirrors to concentrate the sunlight on a central boiler that sits atop a tower roughly 100 meters above them. Brightsource expects its first commercial facility—at 400 megawatts, one of the largest solar plants in the world—to be operating in Ivanpah, CA, by late 2011.

But as with the solar plant in Chicago, the stimulus money will be critical to the viability of the project, which will cost roughly

$2 billion to build. The federal loan program, which provides for direct lending from the U.S. Treasury, could cover 60 percent of the cost. That would require the company to raise only $800 million from investors, who then would be eligible for $600 million in the form of refundable tax credits. (The investment tax credit for renewable energy existed before the stimulus package passed, but the legislation made a key change: it now gives investors an option to receive a direct grant equivalent to 30 percent of their investment, whereas previously they had to apply the credit toward any tax liability they might have.)

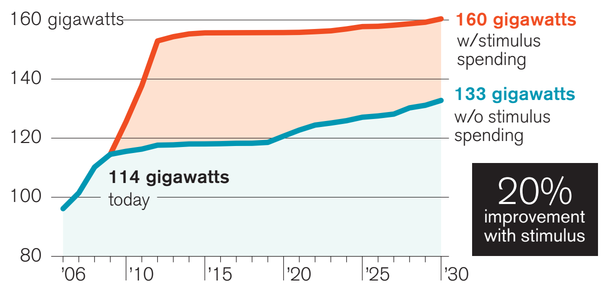
Jack Jenkins-Stark, Brightsource's CFO, is responsible for making the numbers work. "It's all about capital," he says. The cost of operating the plant will be minimal—"maybe $20 million a year." But finding a $2 billion loan to cover the construction costs became nearly impossible after the commercial lending and debt markets collapsed last fall. The only practical way to find such financing these days, he says, is by pairing the federal loan with financing from investors encouraged by the government incentives.

But the federal money, as Jenkins-Stark is quick to point out, comes with plenty of risks. The loan, of course, will have to be paid back. And though finding investors willing to risk several hundred million dollars to build a giant solar plant using new technology is "much easier" with federal incentives in place, he says, "it is still very hard."

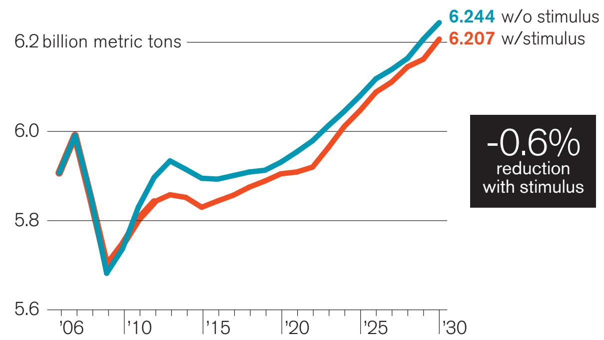
It's a challenge that Arnold Goldman, for one, is happy to take on. Undeterred by the bankruptcy of his earlier solar empire, Goldman now envisions massive solar thermal plants across a wide swath of Nevada, California, New Mexico, and Arizona. This time, though, Goldman could be part of something even bigger. Nearly six gigawatts' worth of new solar thermal capacity is planned in California alone. But, says Goldman, "we need a predictable policy environment."

POWERING UP

U.S. renewable generating capacity forecast through 2030



U.S. energy-related carbon dioxide emissions through 2030*



Source: Energy Information Administration
**Includes increases in renewable energy and energy efficiency*

CATCHING SOME RAYS

About the same time in the mid-1980s that Arnold Goldman was filling the Mojave with mirrors, Richard Swanson, then a professor of electrical engineering at Stanford University, founded his company, SunPower. Both men had visions of large solar plants spread across the desert. But while Goldman was intent on making electricity by turning the sun's energy into steam, Swanson—an expert on semiconductors and microelectronics—envisioned using photovoltaic cells built from precisely manufactured silicon wafers.

In a dusty field in back of SunPower's headquarters in San Jose, Swanson shows off the technology that, if all goes well, Exelon will install in Chicago. A row of large solar panels, mounted on a tracking apparatus, tilts imperceptibly every few minutes so the panels can follow the sun; each panel holds dozens of high-efficiency solar cells of the type that Swanson developed at Stanford. A solar-powered motor wheezes slightly every time it moves the panels. At night, the motor will swing the panels toward the east, waiting for the next day's rising sun.

Swanson's cells are among the most efficient commercially available forms of photovoltaic technology; they convert around 22 percent of the sunlight hitting them into electricity. (The solar panels in Chicago will produce about two-thirds as much power as they would in a sunnier location.) But the panels and wheezing motor are also a stark reminder of just how difficult it has been to make silicon photovoltaics cheap enough to compete with more conventional sources of electricity.

Right now, with the 30 percent investment tax credit, the cost of energy from a photovoltaic plant in a sunny region is competitive with electricity produced by fossil fuels during peak hours, says Swanson. But that is the best-case scenario for solar. In less sunny regions and at times other than the middle of the day, when

electricity prices are high and solar cells are most efficient, the power produced by photovoltaics is still far too expensive.

Dozens of startups have formed in recent years to pursue technologies that their founders hope will be more cost effective. To Swanson's mind, however, the attention given to these efforts is misplaced. The cost of electricity from silicon photovoltaics is decreasing by 5 to 8 percent a year as the industry grows at a rapid pace, he says; within five years, as the existing technology improves and manufacturers realize economies of scale, it will be competitive without federal incentives.

"We don't need a breakthrough," Swanson says. "Waiting for the next big breakthrough [in photovoltaics] will do nothing but cause you to grow moss underneath your feet." He adds, "We have a road map where we can very clearly see how to halve the cost from where we are today. And that is sufficient to fuel explosive industry growth."

TURNING THE CORNER

The solar industry might not need a breakthrough to continue healthy growth rates. But many scientists say that without dramatic advances, solar power will never supply the vast amount of power needed to eventually displace fossil fuels.

Of the 46 new energy research centers announced by the secretary of energy in late April, 24 are doing work related to solar power, and each is receiving $2 million to $5 million annually over the next five years. Likewise, two of the eight new DOE innovation hubs will focus on solar technologies: one on electricity and the other on techniques for storing the energy from sunlight in the form of fuels. And the proposed 2010 DOE budget, which (coming just a few months after the stimulus bill) contained relatively modest increases for most new energy technologies, nearly doubled the research budget for solar power.

Much of the research focuses on overcoming the fundamental dilemma of photovoltaic technology: the trade-off between cost and efficiency. Conventional solar cells are efficient because the silicon from which they're made is grown as a single crystal, yielding a perfectly ordered molecular structure; when the semiconductor absorbs sunlight, the light's energy excites electrons that can travel through this crystal structure unimpeded, escaping to create an electrical current. But making devices out of single-crystal silicon is relatively difficult and expensive. Newer photovoltaic technologies use materials that have a less ordered structure and can be deposited as thin films; they are potentially easier and cheaper to make, but they're also less efficient.

"With photovoltaics you have either high efficiencies or low cost, but what we urgently need are [photovoltaics] with both attributes," says Harry Atwater, a professor of physics and materials science at Caltech. "One of the challenges of solar power is how to get hundreds of gigawatts to a terawatt of power in a way that is cost effective." Achieving that, he says, may take technology "very different than what we use today."

Atwater will head a DOE-funded energy research center at Caltech, where scientists will work on developing materials that could enable thin-film photovoltaics to absorb sunlight more efficiently. These materials, whose microstructure is designed to interact with light in new ways, could be made using different types of semiconductors. Light that strikes solar cells made from them, Atwater says, can be forced to "turn a corner" and travel parallel to the surface of the thin film. As a result, the cell has a chance to absorb much more light than it would if the light passed through perpendicular to the surface.

Researchers elsewhere are hoping to overcome the challenges inherent in using disordered materials for photovoltaic cells. When light strikes the jumble of molecules in such materials, the excited electrons and the electron "holes" left behind when they're knocked free form particle-like pairs called excitons. Excitons play a role in the process that plants use to capture energy through photosynthesis, says Marc Baldo, a professor of electrical engineering at MIT; in addition, organic light-emitting diodes use them to generate light. And, he says, it might be possible to manipulate these excitons on the nanoscale to improve the photovoltaic properties of disordered materials. Baldo heads a DOE-funded energy research center for excitonics, which includes researchers from MIT, Harvard University, and Brookhaven National Laboratory.

Ultimately, however, using sunlight to produce electricity will never supply enough of the energy we need: existing solar technologies, after all, produce power only during the day, and electricity can't easily be stored. Instead, we must find a way to use sunlight to make fuels such as hydrogen, which can readily and cheaply be stored until they're needed.

Learning how to efficiently make such fuels directly from the sun—a process called artificial photosynthesis, because the aim is to essentially mimic the natural process used by green plants—is "still 20 to 30 years down the road," says Harry Gray, a chemist at Caltech and director of a solar-research collaboration that includes scientists from a number of universities. Although researchers, including some in his group, are getting "nice results" on certain aspects of artificial photosynthesis, lots of difficult problems remain to be solved. "It's going to take a long time to get it together," he says.

Silicon photovoltaics will be the dominant solar technology "for quite a while," says Gray. "If all goes well, we will move into cheaper solar cells that are not single-crystal silicon, such as organic photovoltaics. But the transition [to cheaper photovoltaics] is not going to come all that fast."

FLYING TOMATOES

Will the stimulus bill facilitate that much-needed transition to more efficient technologies? Severin Borenstein, for one, is

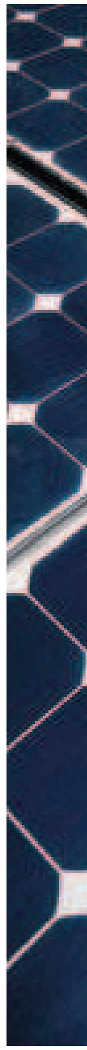
doubtful. Borenstein, the director of the University of California Energy Institute, says the problem with the stimulus funding is that when it comes to existing technologies, the DOE will need to pick which projects to support. "The worry is that the government will invest in the wrong technologies," he says; picking technology winners is something that "historically it has not been very good at." A far more effective way to promote the growth of renewable energy, he believes, is to put a price on carbon dioxide emissions through a carbon tax or a cap-and-trade scheme *(see "Carbon Trading on the Cheap," p. 72)*. Either approach would provide market-based incentives for deploying renewables and would represent a more efficient and "technology-neutral" government policy. At the same time, he says it is important for the government to fund research into new renewable technologies.

From an economist's perspective, Borenstein says, government subsidies are justified to address "market failures": cases in which the market doesn't allocate enough resources to the pursuit of socially desirable goals, such as reducing greenhouse-gas emissions. The government incentives then support efforts that are financially risky but are likely to provide a common benefit. In such a context, he says, the argument for public spending on research into new solar technologies is strong—but the case for subsidizing the current commercial technologies, particularly photovoltaics, is "really weak." Existing photovoltaics are expensive even compared with other renewables such as wind and solar thermal, he says, and they won't necessarily lead to cheaper technologies, either. "You're obviously going to get [solar] panels put in, but is that going to generate something that will have a lasting benefit? Will it help you build a solar industry? I think the answer is probably not."

Borenstein says direct government subsidies to support existing photovoltaics could in fact impede the development of more efficient technologies. "There is no question that there is what economists call 'option value' lost when you invest in the current technology," he says. "If the technology is about to get a lot better, and is about to get a lot better for reasons that don't have to do with building out the current technology but because the science is going to improve, that's an argument for waiting. You're crowding out future investment by investing now. The money would be better spent five years from now on the new technology."

In a recent paper, researchers at Carnegie Mellon University's Department of Engineering and Public Policy surveyed leading solar-power experts on the future of photovoltaics and concluded not only that the technology is far more expensive than other renewable sources of energy, such as wind and even solar thermal power, but that it "may have difficulty becoming economically competitive" in the next 40 years. The results are "dismaying," says Granger Morgan, a Carnegie Mellon engineering professor and the department's head.

Short-term subsidies for wind and solar thermal power could help them become cheap enough to compete with conventional sources of electricity, Morgan says. "But silicon photovoltaics are really a different matter. With existing technology, I just don't see it happening." He doubts that even doubling or tripling the use of current photovoltaic technologies will dramatically bring down the prices. "Of course," he says, "if you get up in a room and say this, the tomatoes start flying."



POWER ANGLE Photovoltaic panels built by SunPower are on a tracking apparatus that moves the solar cells during the day to follow the sun. The panels, shown here at SunPower's headquarters in San Jose, CA, are moved by a solar-powered motor. The company says its solar cells, which use a design created by founder Richard Swanson, a former Stanford professor, are the most efficient commercial photovoltaics.

ERIK PAWASSAR

Indeed, plenty of experts believe that existing photovoltaics have an important role to play in promoting new forms of solar power. Deploying them on a larger scale will "pave the way for the next technologies," insists Lawrence Berkeley's Alivisatos. For that reason, he says, it is important to establish photovoltaics in the market. "It makes sense to have an industry that can gear up now," he says. "Hopefully, that industry will absorb the new developments and bring out newer products over the next couple of decades."

Caltech's Harry Gray agrees: the urgency in his voice is palpable when he argues that we need to install as much solar power as we can, as soon as possible. "We need to make investments now in the technology we have, which is silicon photovoltaics," says Gray. "We should be putting in [solar power] everywhere we can so people can see that it can make a difference. We can't sit back and wait for breakthroughs. We need to show people that solar can work."

The disagreement on the role of solar photovoltaics illustrates the larger debate over the best way for government policy to encourage a national shift to cleaner energy. And it is about to be played out around the country.

The DOE will probably decide soon on Exelon's loan application to build the Chicago solar plant. If it gets built, the facility will represent only a tiny fraction of the nation's total solar capacity, or even of Exelon's electricity portfolio. But Gray is surely right on one point: such a facility, located in one of the nation's largest cities, would be the face of solar power for many. Its fate will matter.

According to accounts by several companies, the DOE is thorough in reviewing the hundreds of loan applications it's received, rigorously evaluating the financial health of the applicants and the market potential of proposed facilities. Nevertheless, it is hard to ignore the role of politics in deciding whether Exelon will build its facility on the South Side of Chicago. After all, President Obama's home is just 13 miles away, and local politicians have been trying for years to reinvigorate the neighborhood that surrounds the site.

But then, politics have always played a major role in deciding the nation's energy future, especially when it comes to solar power. Just ask Arnold Goldman. TR

DAVID ROTMAN IS THE EDITOR OF *TECHNOLOGY REVIEW.*

BRIEFING

CLOUD COMPUTING

JAMES GULLIVER HANCOCK

Just another online fad—or the biggest revolution since the Internet?

According to its advocates, cloud computing is poised to succeed where so many other attempts to deliver on-demand computing to anyone with a network connection have failed. Some skepticism is warranted. The history of the computer industry is littered with the remains of previous aspirants to this holy grail, from the time-sharing utilities envisioned in the 1960s and 1970s to the network computers of the 1990s (simple computers acting as graphical clients for software running on central servers) to the commercial grid systems of more recent years (aimed at turning clusters of servers into high-performance computers). But cloud computing draws strength from forces that could propel it beyond the ranks of the also-rans.

Rather than running software on dedicated hardware—a mail server here, a database host there—cloud systems can let software run on virtual machines, simulated systems generated at a moment's notice in massive data centers *(see "Water-Powered Computers," p. 58)*. If a customer's needs expand, more virtual machines can be created and configured with

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ease, and should those needs later decline, the underlying hardware resources are returned to the data center's pool.

No elaborate construction or development program is needed to kick-start such technology—the infrastructure is already in place and making money. Existing data centers, built to support the likes of Amazon and Google, can rent spare capacity, creating a collection of services that provide the illusion of infinite computing power and storage on tap. Technologies like virtualization *(as explained in "Conjuring Clouds," right)*, combined with growing market pressures to reduce capital spending *(see "Virtual Computers, Real Money," p. 61)*, could revolutionize the software industry, enabling startups to offer online applications or services without investing much in storage, Web, or e-commerce infrastructure. End users could have seamless access to applications and data anywhere, on any device.

As reported in "Making Art Pay" *(p. 57)*, eliminating the need for infrastructure investment allows rapid development of applications. An ecosystem of startups has sprung up to provide platforms, tools, and expertise—recently joined by companies such as IBM and Intel *(see "Companies to Watch," p. 62)*. As a still-maturing technology, however, cloud computing has yet to overcome certain challenges, such as guaranteeing the integrity and security of users' data, providing a seamless user experience, and establishing standards to allow companies to move from provider to provider *(see "The Standards Question," p. 59)*. A number of key players are driving many of the industry's responses to these challenges, and open-source efforts and academic research consortiums are likely to play a role as well *(see "Open-Source Projects and Research Consortiums," p. 63)*.

A survey of corporate software buyers by the 451 Group showed the use of public cloud computing increasing by more than 60 percent in the last quarter of 2008 over the previous two quarters, and International Data Corporation has predicted that business IT spending on cloud services will rise from $16 billion last year to $42 billion by 2012, setting up cloud computing as one of the few areas of growth in an otherwise gloomy economy. *–Stephen Cass*

TECHNOLOGY OVERVIEW

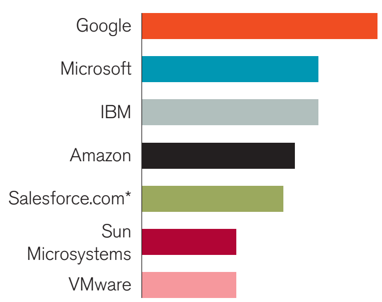
Conjuring Clouds

HOW ENGINEERS ARE MAKING ON-DEMAND COMPUTING A REALITY

Much of the popularity of cloud computing is owed to a technology known as virtualization. A host computer runs an application known as a hypervisor; this creates one or more virtual machines, which simulate real computers so faithfully that the simulations can run any software, from operating systems to end-user applications. The software "thinks" it has access to a processor, network, and disk drive, just as if it had a real computer all to itself. The hypervisor retains ultimate control, however, and can pause, erase, or create new virtual machines at any time. Virtualization means that e-mail, Web, or file servers (or anything else) can be conjured up as soon as they're needed; when the need is gone, they can be wiped from existence, freeing the host computer to run a different virtual machine for another user. Coupled with management software and vast data centers, this technology allows cloud providers to reap massive economies of scale. And it gives cloud users access to as much computing power as they want, whenever they want it.

BIG SEVEN

A survey of 1,771 firms showed they plan on using these public cloud vendors by mid-2009



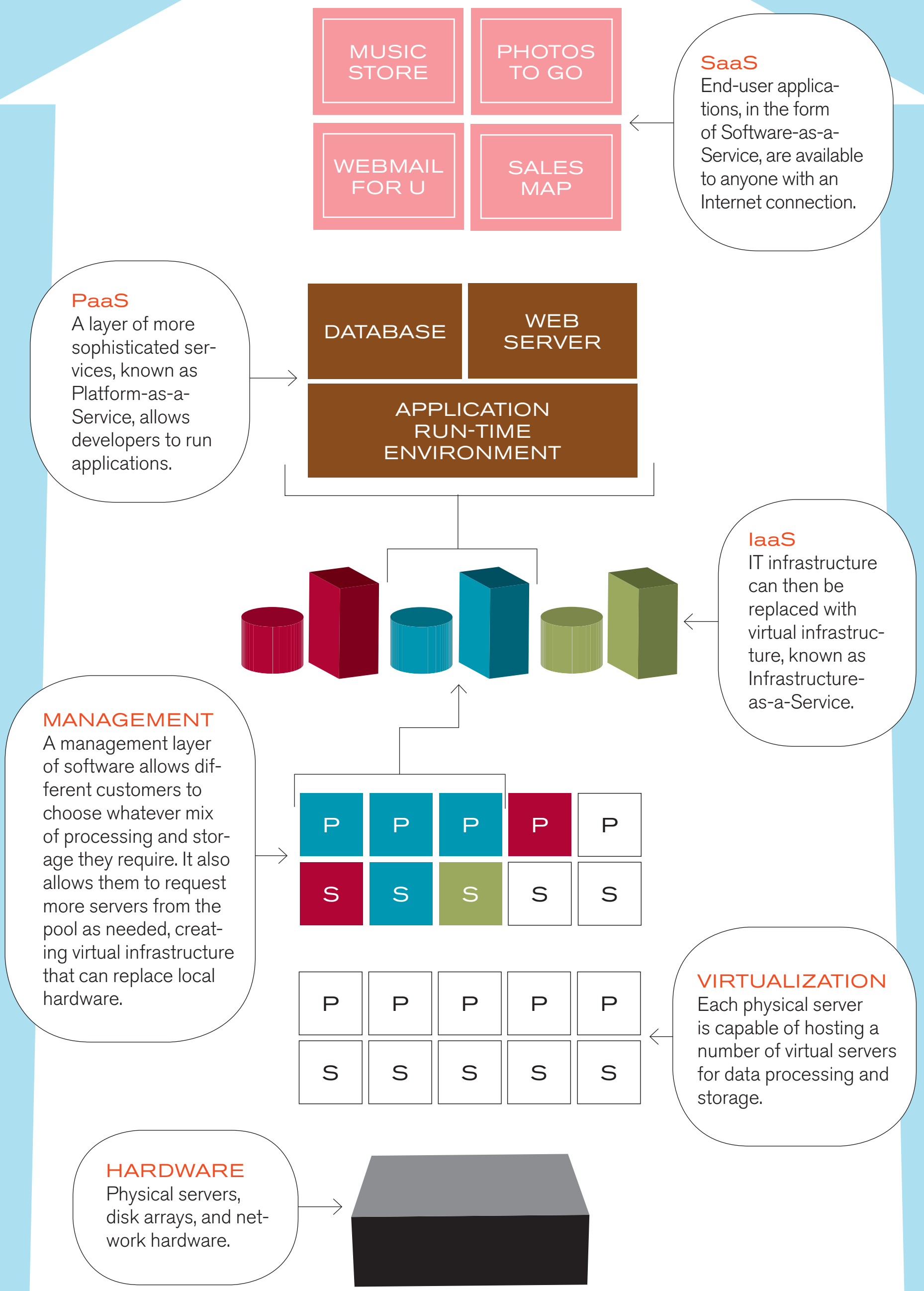
Source: The 451 Group

The dream of on-demand computing—a "utility" that can bring processing power into homes as readily as electricity or water—arose as soon as computers became capable of multitasking between different users. But early attempts to create this capacity were too restrictive—for example, limiting users to a particular operating system or set of applications. With virtualization, a user can write applications from scratch, using practically any operating system. And users don't have to write their own applications: cloud providers, and companies that partner with them, can offer and customize a variety of sophisticated services layered on top of the basic virtual machines. This means that developers interested in, say, rolling out a new social-networking website don't need to design and deploy their own supporting database or Web servers. By allowing users and developers to choose exactly how much they want in the way of computing power and supporting services, cloud computing could transform the economics of the IT and software industries, and it could create a whole raft of new online services *(see "Virtual Computers, Real Money," p. 61)*.

"Cloud computing is a reincarnation of the computing utility of the 1960s but is substantially more flexible and larger scale than the [systems] of the past," says Google executive and Internet pioneer Vint Cerf. The ability of virtualization and management software to shift computing capacity from one place to another, he says, "is one of the things that makes cloud computing so attractive."

Virtualization technology dates backs to 1967, but for decades it was available only on mainframe systems. When data centers became common during the Internet boom of the 1990s, they were usually made up not of mainframes but of numerous inex-

TOMMY McCALL



THE STACK

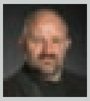
Many clouds rely on virtualization technology that allows computers to simulate many processing and storage servers. Starting with hardware located in data centers, a series of software layers allow these virtual servers to be created and configured on demand. Once a customer no longer needs a virtual server, it can be erased, releasing the underlying hardware resources to serve another computer. By providing computing power in such an elastic way, clouds enable companies to avoid paying for power they don't need.

pensive computers, often based on the x86 chips found in PCs worldwide. These computers had hardware idiosyncrasies that made virtualization difficult. While companies like VMware offered software solutions in the late 1990s, it wasn't until 2005 that Intel (soon followed by its rival AMD) offered hardware support for virtualization on x86 systems, allowing virtual machines to run almost as fast as the host operating system.

Even with the new support, you can't just "plug in a server" and expect to use it for cloud computing, says Reuven Cohen, founder of the cloud-computing platform company Enomaly and the Cloud Computing Interoperability Forum. Instead, cloud computing relies on a series of layers. At the bottom is the physical hardware that actually handles storage and processing—real servers crammed into a data center, mounted in rack upon rack. Although companies are loath to disclose the size of their data centers, John Engates, CTO of Rackspace, says that hosting companies typically build them out in modules of 30,000 to 50,000 square feet at a time. Running on the hardware is the virtualization layer, which allows a single powerful server to host many virtual servers, each of which can operate independently of the others. Customers can change configurations or add more virtual servers in response to events such as increases in Web traffic. (It should be noted that not every cloud provider uses virtual servers; some combine the resources of physical computers by other means.)

Then comes the management layer. In place of platoons of system administrators, this layer distributes physical resources where they're needed, and returns them to the pool when they're no longer in use. It keeps a watchful eye on how applications are behaving and what resources they're using, and it keeps data secure. The management layer also allows cloud companies to bill users on a true pay-as-you-go basis, rather than requiring them to lease computing resources in advance for fixed periods of time. Better billing may seem like a small detail, but it has turned out to be a key advantage over earlier attempts to create on-demand computing.

KEY PLAYERS

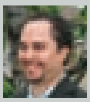


WERNER VOGELS
Amazon

The CTO of Amazon.com brought cloud computing to the masses in March 2006, when he started selling the spare capacity of Amazon's massive server infrastructure to anyone with a credit card.

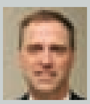
JIM BLAKLEY
Intel

Blakley is the director of datacenter virtualization at Intel, which is developing energy-efficient processors and solid-state hard drives for cloud systems—a big deal for data centers that suck down megawatts of electricity.



REUVEN COHEN
Enomaly

The founder and CTO of Enomaly, which develops software to help companies create and manage cloud systems in their data centers, Cohen was instrumental in proposing the Open Cloud Manifesto, calling for interoperability standards among cloud providers. The recent proposal has sparked a heated debate in the industry.



DAVE DOUGLAS
Sun

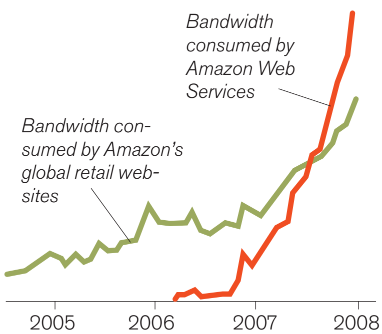
Douglas led the launch of Sun's Open Cloud Platform in March of this year. He is a supporter of the Eucalyptus open-source cloud project, which could help provide de facto standards for cloud computing.

Cloud providers can offer services on top of the management layer, allowing customers to use cloud-based infrastructure in place of physical hardware such as Web servers or disk arrays. Amazon Web Services' Simple Storage Service (S3), for example, allows customers to store and retrieve data through a simple Web interface, paying about 15 cents per gigabyte per month in the United States (with some additional charges for data transfers). The Elastic Compute Cloud (EC2), also from Amazon, provides virtual computers that customers can use for processing tasks. Prices range from 10 cents per hour to $1.25 per hour, depending on the size of the virtual computer and the software installed on it.

Beyond infrastructure offerings, however, companies are also providing more sophisticated services, including databases for managing information and virtual machines that can host applications written in high-level languages such as Python and Java, all of which can help developers get a new service or application to market faster. Google's App Engine, for example, gives customers access to the technologies underlying Google's own Web-based applications, including its file system and its data storage technology, Bigtable. Even when these services don't use a layer of virtual servers (App Engine does not), they still allow users to expand and contract their usage with the flexibility that is the hallmark of cloud computing.

BLASTOFF

Demand for Amazon's new cloud soared



Source: Amazon.com

Perched on top of all these layers are the end-user applications, such as online calendars or programs for editing and sharing photos. By encouraging content sharing and loosening the limits imposed by our computers' local processing abilities, these applications are changing the way we use software. While some—such as Web mail—predate clouds, building such services on clouds can make them more appealing says Rick Treitman, entrepreneur in residence at Adobe Systems and a driving force behind the Acrobat.com suite of applications (which do their computations on a user's computer but draw data from a cloud as needed). For consumers, Treitman says, what's most attractive about cloud applications is their constant availability, regardless of the user's operating system or location, and the ease with which multiple users can share data and work together. But he notes that these qualities can come into conflict: allowing offline access to data stored in cloud applications, for example, offers a convenience to users but can create problems if multiple users access a document, change it offline, and then try to synchronize their efforts. (For more about some of the technical challenges facing cloud computing, see "The Standards Question," p. 59.) While Amazon and other providers make cloud services publicly available, some companies are turning to cloud-computing technologies inside their own private data centers, with the goal of using hardware more efficiently and cutting down on administrative overhead. And once a company sets up its own private cloud, it has a chance to take advantage of additional flexibility. For example, a specialty of Cohen's company, Enomaly, is setting up overflow computing, also known as cloud bursting. A company can host its Web services and applications in its own data centers most of the time, but when a spike in traffic comes along, it can turn to outside providers for supplemental resources instead of turning customers away.

Ultimately, clouds could even change the way engineers design the computers that are increasingly embedded in everyday objects such as cars and washing machines. If these low-powered systems can reach out and draw any amount of computing power as needed, then the sky's the limit for what they might do. —*Erica Naone*

CASE STUDY

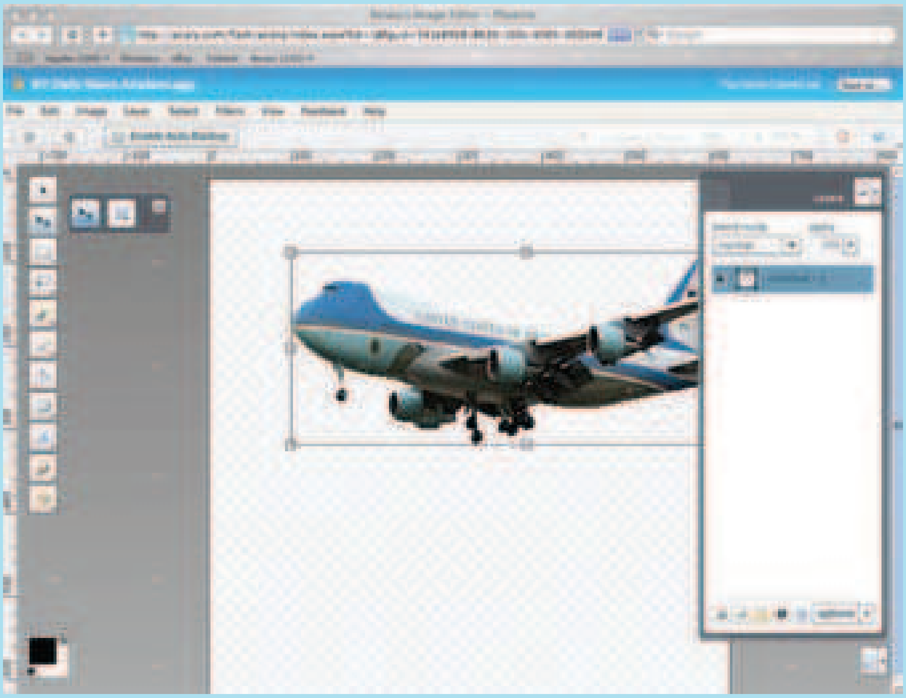
Making Art Pay

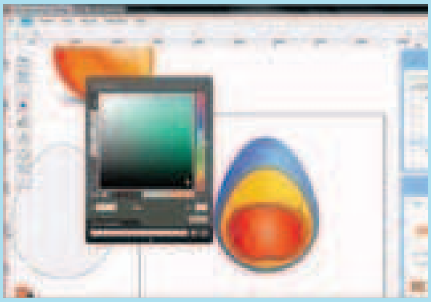
A STARTUP SEEKS TO UNDERCUT PHOTOSHOP WITH SUBSCRIPTION SOFTWARE

By reducing development costs and making new features possible, cloud computing promises to create opportunities for software developers. A New York–based startup called Aviary is hoping to cash in on that promise by offering graphics programs that compete with far more expensive software.

Founded in 2007, Aviary uses Adobe's Flex, a general-purpose platform for developing Internet-based applications, to make software that lets people modify photos, create illustrations, and share the results. Aviary's applications run in Flash, through the Web browser on a user's computer. Images are saved to the company's private servers rather to a local disk drive—the conventional way of storing files. The private servers are continuously backed up to Amazon's S3, a service that provides bulk online storage. If Aviary's servers become overwhelmed because of, say, a glut of users, the system stays afloat by transferring files from S3 to users instead.

Aviary's software development process has been the work of just a dozen or so programmers, and it has afforded a quick return on their effort. Because they can update the software as often as they like without requiring users to install patches or upgrades, a working version of an application can be rolled out the door as soon as it's complete, with refinements made later. Matt Wenger, president and CEO of the software company GroupSystems, says that cloud applications can be cheaper to develop than other types of applications, especially because it removes the need to worry about how





Aviary's software (left) allows anybody with a Web browser to draw illustrations or edit photographs. The *New York Daily News* invited readers to create their own version of Air Force One's ill-advised flyover of Manhattan in April (above).

"You write one version and you install it in your own controlled environment, and any changes are tested in that environment. ... You spend hundreds of hours less in support over the life of a product."

and where users install software. "You write one version of the application and you install it in your own controlled environment [on your servers]," he says, "and any changes are tested and rolled out in that environment. The net of it is that you spend hundreds of hours less in support over the life of a product for a group of customers."

But while cloud computing can make product development and marketing more efficient, it has its own quirks. For example, Aviary needed a way to save huge image files quickly across a network. "An artist's work flow generally requires frequent saving," says Avi Muchnik, Aviary's founder. "This means that we'd theoretically need the capability to send huge files multiple times in the span of a few minutes." But constantly sending large image files back and forth over the Internet would strain Aviary's servers and frustrate users with

slow connections. The company's solution is to detect incremental changes and transfer only those small pieces of the file that have changed.

Cloud computing provides more than just convenient storage. When artists allow people to use and modify their work through other media-sharing websites, the result can be a free-for-all. But Aviary tracks changes in images, so there is a record of how the work has been used. Artists can even levy royalties, which Aviary's software enforces automatically. If a person creates an image and assigns it a royalty of 50 cents, and another artist incorporates it into a composite work and wants to sell it, the second artist would have to sell the composite image for at least 50 cents, with that money going back to the original creator. This easy royalty-sharing scheme creates a business model for artists that would have been impossible without cloud computing.

Aviary's software offers fewer features than Adobe's Photoshop and Illustrator, the gold standard among graphic designers and artists. But converts like Shawn Rider, manager of technology solutions at PBS, say they like it because they can access files from any Internet-connected computer and collaborate easily with other users, all for a very low price. Aviary offers access to a free version of its software with basic design tools. For $9.99 a month, users get more features as well as access to the royalty-sharing system.

Aviary also provides an application programming interface (API), which allows other businesses to integrate its image-editing tools into their websites. The *New Yorker* has used the tools for a cartoon contest, and the *New York Daily News* recently held a photo-editing contest to alter the image of Air Force One's embarrassing flyover of New York City in April.

As for the future, Aviary is looking beyond image editing. In March, the startup acquired Digimix, a small company that makes Web software for audio editing; it may also start developing software for inexpensive online video editing, which should have a ready market among the hordes of YouTube contributors. *—Kate Greene*

MAP

Water-Powered Computers

Cloud computing makes believe that physical location is irrelevant. Your data and applications can all live somewhere on the Internet, accessible to you anywhere, anytime—as long as you have a network connection. But the illusion of spatial irrelevancy is belied by the placement of some data centers in very particular geographic locations indeed.

In addition to bandwidth, data centers need electricity. Lots of it. The U.S. Environmental Protection Agency estimates that U.S. servers and data centers were responsible for a total of 1.5 percent of America's electricity consumption in 2006 (about 61 billion kilowatt-hours), at a cost of $4.5 billion, and that their consumption will double by 2011. Not surprisingly, data-center owners have searched out sources of cheap electricity in the hydroelectric dams that dot the Rockies and the Northwest. Washington and Oregon, America's top two hydroelectric-producing states, have electricity costs 20 to 30 percent lower than the national average. As a result, small towns in places like the Columbia River basin (above) are enjoying a data-center gold rush, often helped by local authorities who are willing to provide owners with fiber-optic connections to the rest of the world. — *Stephen Cass*

ARTHUR MOUNT

INDUSTRY CHALLENGES

The Standards Question

SECURITY AND RELIABILITY AREN'T THE ONLY PROBLEMS FOR CLOUD USERS AND PROVIDERS

Cloud computing involves the movement of content and applications from personal computers and private data centers to platforms floating somewhere in cyberspace. Users are tethered to their digital property only by an Internet connection; someone else provides and maintains the hardware and software supporting the services they use. Ideally, this shouldn't give users anything to worry about. Reality, of course, is different. "We still have a long way to go to define what clouds can do and how users should interact with them," says Vint Cerf, a father of the Internet who is now a vice president and chief Internet evangelist for Google.

Customers are typically concerned about the security and reliability of cloud providers' operations. High-profile cases have reinforced those concerns—most notably when, earlier this year, the social bookmarking site Ma.gnolia.com irretrievably lost about half a terabyte of user data. "When there's an outage, they end up in the *New York Times*," James Staten, an analyst at Forrester Research, says of the cloud providers. "If there's a significant security hole, they end up there too."

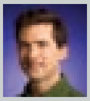
Cloud users have the option of taking security into their own hands, says John Landwehr, director of security solutions and strategy at Adobe Systems. Some newer systems, including Adobe's own LiveCycle Rights Management ES software, encrypt sensitive documents so engineering applications must "phone home" to check a user's credentials before allowing a document to open. Such measures can head off some of the worries that arise when data and applications are stored remotely on virtual servers owned and managed by another company.

But there are other, potentially tougher problems—for example, the limitations of bandwidth and the architecture of today's Internet. Customers who want to use clouds to process very large data sets sometimes find that the time it takes to send the data to the cloud provider can negate any time savings gained from drawing on its computational power. "Most of the challenge has to do with the fact that you're accessing the cloud over the public Internet," explains John Engates, CTO of the hosting company Rackspace. "Everybody thinks of the Internet as perfect, but it's not … when you're copying mountains of data across it, there are going to be failures." And resending data that has been corrupted in transit makes transmission times even longer. Nick McKeown, director of the Clean Slate Design for the Internet project at Stanford, says that this problem will probably get worse before it gets better. "Everything will be moving around. Computation will move around, users will move around, data will move around," he says. "Until now, the Internet's solution to mobility has been a hack, retrofitted to an old and

"Everybody thinks of the Internet as perfect, but it's not… when you're copying mountains of data across it, there are going to be failures."

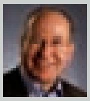
JAMES GULLIVER HANCOCK

KEY PLAYERS



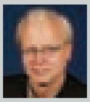
KEVIN GIBBS
Google

The technical lead for Google App Engine, a platform launched in 2008 that hosts and offers services for Web-based software, Gibbs is extending App Engine beyond low-cost startups to corporate users, allowing them to create larger-scale applications.



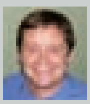
KRISTOF KLOECKNER
IBM

IBM's cloud-computing CTO oversees the Blue Cloud series of products. Kloeckner is an advocate for open standards and software, and he wants public clouds to be interoperable with those that run on private data centers.



RAY OZZIE
Microsoft

Microsoft's chief software architect is leading the company away from its roots in PC software toward applications and services that run remotely on servers. Ozzie is trying to develop a cloud-based system that unifies the software across devices, from mobile phones to television screens.



JAMES URQUHART
Cisco

Urquhart, the product marketing manager for cloud computing and virtualized data centers at Cisco, influences the design of critical cloud hardware. An early evangelist for cloud computing, he writes The Wisdom of Clouds, a popular blog on the subject.

RAINY DAYS

Some recent hiccups cast doubt on the reliability of cloud services.

Company	Date	Event
Google	May 14, 2009	An accidental redirection of Web traffic through Asia caused slowdowns and interruptions for about 14 percent of customers trying to use the company's search, mail, and other services.
Ma.gnolia	January 30, 2009	The social bookmarking service lost about half a terabyte of data, including the backup files, when a database became corrupted. The fiasco forced the service to shut down, but Ma.gnolia hopes to relaunch later this year.
Apple	July 10, 2008	MobileMe was designed to tie a user's e-mail, contacts, and calendars together across multiple devices, replacing a similar service called .Mac. But when it launched, some customers became unable to access e-mail or lost it altogether.
Amazon	February 15, 2008	When the company's cryptographic authentication system became overwhelmed, its Simple Storage Service (S3) went offline for about two hours, provoking a wave of concern from startups and other companies that rely on it.

ossified architecture. This isn't going to be good enough for cloud computing—we need more innovation in the architecture."

Another issue is making cloud applications as reliable to use as locally running software, even in the face of a spotty network connection. Apple's MobileMe cloud service, which stores and synchronizes data across multiple devices, got off to an embarrassing start last year when many users were left unable to access mail and synchronize data correctly. To avoid such problems, providers are turning to technologies such as Google Gears, Adobe AIR, and Curl, which allow cloud-based applications to run locally; some even allow them to run in the absence of a network connection. These tools give Web applications access to the storage and processing capabilities of the desktop, forming a bridge between the cloud and the user's own computer.

But perhaps the biggest issue is the lack of standards, says Reuven Cohen, founder and CTO of cloud-computing provider Enomaly. Right now, if a company starts using the cloud services of one provider, it's effectively locked in, dependent on that provider. Cohen believes that companies should be free to move their data to whichever cloud provider they want to work with at any time. In the absence of standards that would make this possible, companies such as the startup Cloudkick have sprung up to help users move data from one platform to another.

Mike Evans, vice president of corporate development at the open-source technology provider Red Hat, compares clouds today to the earliest online communities, such as CompuServe and America Online. "They were all siloed communities," he says. "You couldn't necessarily interoperate with anybody else until the openness of the Internet came along." Evans believes that open-source projects are "critical" to establishing standards that would encourage more companies to use cloud technology.

Two broadly supported open-source projects may help pave the way for such standards. Eucalyptus, which uses an interface familiar to those experienced with Amazon's Elastic Compute Cloud, provides the means to create a cloud either within a private data center or with resources from a cloud provider. And Hadoop imitates elements of Google's system for handling large amounts of data.

For the moment, Amazon Web Services seems to be the de facto standard, and the company appears not to be interested in defining more formal standards, which would inevitably force it to give up some control over its platform and make it easier for other providers to compete. Says Adam Selipsky, vice president of product management and developer relations for Amazon Web Services: "We think it's very early to understand not only what the standards are, but along what dimensions standards are even useful." —*Erica Naone*

MARKET WATCH

Virtual Computers, Real Money

WILL CLOUDS BE DOMINATED BY A FEW BIG PLAYERS?

At first blush, companies' demand for cloud computing seems rooted in their desire to save money. Because cloud services can be quickly rented on a pay-as-you-go basis, companies can avoid purchasing extra equipment in anticipation of inevitable, but unpredictable, peaks in demand. For IT executives whose budgets are shrinking during an economic downturn, "that's a huge ticket to take to their boards," says William Fellows, an analyst at the 451 Group, which studies enterprise technology. "They're being told to cut costs and do the same with less."

But cloud computing isn't only about cheaper IT; the technology also offers companies the flexibility essential for survival. "The economy has become much more volatile, not just in the past year, but over the past 10 years," says Erik Brynjolfsson, a professor at MIT's Sloan School of Management and the director of its Center for Digital Business. "The ability to be agile in your infrastructure is what separates the winners from the losers … cloud computing is one of the most important technologies that affect the ability to maintain that level of flexibility."

In addition to letting startups bring products to market faster, with fewer developers and minimal initial investment *(see "Making Art Pay," p. 57)*, cloud computing has allowed larger organizations to bypass cumbersome internal IT bureaucracies. "BP found out that tens if not hundreds of its developers were using credit cards to buy resources on Amazon Web Services to circumvent their internal processes," says Fellows.

This suggests that the next big thing in cloud computing will not be an explosion in the number of companies like Amazon and Rackspace, which provide general-purpose, public cloud services, but the conversion of data centers within companies into private clouds. Companies can reap the technology's benefits by sharing resources among business units more efficiently and responding faster to their needs. Fellows says that his clients who have converted report a 30 percent saving on the cost of infrastructure.

Designing private data centers as clouds makes it easier for businesses to supplement their internal resources by tapping public clouds during crunch periods, a phenomenon known as cloud bursting *(see "Conjuring Clouds," p. 54)*. That's possible because both clouds will have similar protocols.

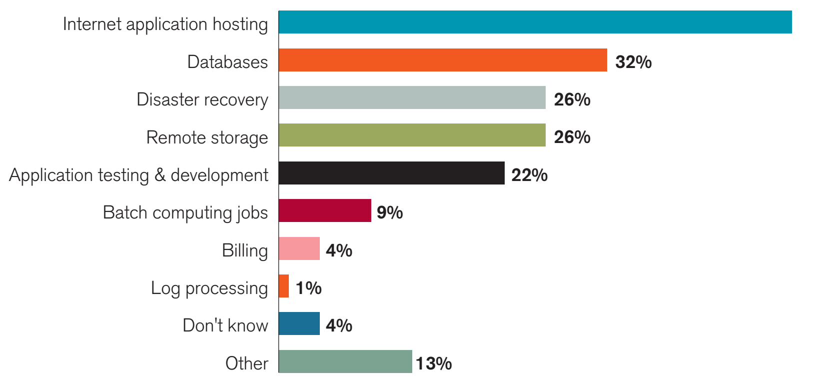
Mike Evans, vice president of corporate development at Red Hat, says that this is also a way for companies to experiment with the technology: "They're not just going to turn over their whole IT department to an external cloud in two months. We're seeing them say, 'Let me figure it out through an internal cloud.'" Fellows adds, "That's the next rash of product offerings that we are going to see—anyone who can bottle some of the magic that Amazon and Google have got and make it available internally for enterprises."

In the longer term, "the real value in cloud computing is not going to be in the underlying hardware and basic services," says Sloan's Brynjolfsson. "They will be relatively close to commodity provisions. It'll be in the value-adding services that go on top of that." He predicts a churn of companies offering services. Even if a company comes to control a market, its dominance will be tenuous, because "if somebody else can do it just a little bit better, they can take over the market quite quickly," he says. "Cloud computing makes it much easier for somebody to do that."

Fellows agrees that public cloud computing will be dominated by a few big players, but because so many businesses will be running private clouds, he thinks there is the possibility of coöperation between them. He believes that these owners could even compete with the big public players by opening up their private clouds to public use for specialized services—essentially, cloud bursting in reverse. Companies will have opportunities to act as brokers between clouds—providing easy ways to switch loads between providers, for example. There are even companies "setting up now to provide exchanges where cloud capacity can be traded like futures," he says. But in that case, "these folks are ahead of their time." —*Stephen Cass*

TOP USES FOR CLOUD COMPUTING

Based on an October 2008 survey of 1,771 companies



Source: The 451 Group

TOMMY McCALL

MARKET TABLES

Companies to Watch

PRIVATE COMPANIES

Name	Year Founded	Number of Employees	Major Investors	Total Invested	Key Product	Technology
10gen www.10gen.com	2008	8	Union Square Ventures	$1.5 million	MongoDB	Sponsors an open-source database that makes cloud applications easier to build.
3Tera www.3tera.com	2004	30	Net One Systems	$3.7 million	AppLogic	Allows customers to move data and applications easily between its cloud platform and private data centers.
Appistry www.appistry.com	2001	35	Stuart Mill Venture Partners	$23 million	Appistry CloudIQ	Makes it possible to move business functions to a cloud while keeping existing systems.
Elastra www.elastra.com	2007	35	Amazon, Bay Partners, Hummer Winblad Venture Partners	$14.6 million	Elastra Enterprise Cloud Server	Helps businesses use public clouds in concert with their internal IT setups.
Enomaly www.enomaly.com	2004	20	Intel	Undisclosed	Elastic Computing Platform	Creates tools that give customers the freedom to change cloud providers.
XCalibre www.flexiscale.com	1997	26	Funded by revenue	N/A	FlexiScale	Helps European startups comply with data protection and export regulations.
ServePath www.gogrid.com	1994	100+	Funded by revenue	N/A	GoGrid	Hopes to beat Amazon by wooing IT administrators with management software that behaves more like the tools they are already familiar with.
Heroku www.heroku.com	2007	11	Redpoint Ventures, Y Combinator	$3 million	Heroku	Allows rapid deployment of systems based on Ruby on Rails, a popular way of building Web applications.
RightScale www.rightscale.com	2006	100	Benchmark Capital, Index Ventures	$22.2 million	RightScale Cloud Management Platform	Provides essential hand-holding for companies wanting to run applications on a variety of public and private clouds.
Joyent www.joyent.com	2004	25	Seed investment from PayPal cofounder Peter Thiel	Undisclosed	Accelerator, Connector	Provides on-demand storage and computing services for Web-application developers.

PUBLIC COMPANIES

Name	Market Cap (in billions)	Cloud Products	Notable Acquisitions and Partnerships	Major Customers	Market Position
Adobe www.adobe.com/products/air	15.6	AIR, LiveCycle ES Developer Express	None	eBay, New York Times, Time Warner	Lets programmers develop cloud-based applications that can use local computing resources when needed.
Akamai www.akamai.com	3.8	EdgeComputing, Web Application Accelerator, NetStorage, Global Traffic Manager	OpSource	MySpace, HP	Rapidly remobilizing its content delivery network for cloud computing.
Amazon aws.amazon.com	37.4	Amazon Web Services	Amazon has made venture investments in Engine Yard and Elastra	Linden Lab (Second Life), Washington Post	Offers à la carte computing power, storage, and Web content delivery.

Name	Market Cap (in billions)	Cloud Products	Notable Acquisitions and Partnerships	Major Customers	Market Position
Google www.google.com/a	137.4	Google Apps (Gmail, Google Docs), App Engine	Postini	Genentech, University of Arizona, city government of Washington, DC	With the launch of App Engine, developers can use Google's infrastructure to host and maintain their own applications.
IBM www.ibm.com/cloud	143.5	Computing on Demand	Outblaze	Indigo BioSystems, Elizabeth Arden, United States Golf Association, University of Pretoria	Its 10 global cloud-computing labs let businesses tap into IBM's computing power and expertise in building and managing data centers.
Intel www.intel.com	92.1	Xeon 5500 processor, Data Center Manager, Node Manager	None		Recently released Xeon 5500 processor could dominate the huge data centers that will be built as cloud computing expands.
Rackspace www.mosso.com	1.3	Mosso Cloud Sites, Cloud Files, Cloud Servers	Slicehost, Jungle Disk	Razorfish, Radio Flyer	Its cloud-computing division, Mosso, is promising more reliability, better support, and less downtime than main competitor Amazon Web Services.
SalesForce.com www.salesforce.com/platform	4.8	Force.com	InStranet	Harrah's Entertainment, Japan Post, New Jersey Transit	With Force.com, the company has created a platform that lets a business's IT staff build and host applications using the company's infrastructure.
Sun www.sun.com/solutions/cloudcomputing	7.82	Sun Open Cloud Platform, Sun Cloud	Q-layer	None yet; product launching in beta this summer	Promising a set of open APIs, the company is launching cloud storage and computing services later this year.
Yahoo research.yahoo.com/cloud_computing	22.7	Yahoo Small Business, Zimbra	Zimbra	Comcast, H&R Block, UCLA	Its popular Web applications and open-source projects keep the beleaguered company in the picture.

OPEN-SOURCE PROJECTS AND RESEARCH CONSORTIUMS

Name	Major Contributors	Purpose
Apache Hadoop hadoop.apache.org	Apache Software Foundation, Yahoo, Google, Microsoft, Cloudera	Has developed an open-source version of Google's MapReduce and File System infrastructure for processing large amounts of data in parallel, a necessity in cloud computing.
Eucalyptus www.eucalyptus.com	Building on an NSF-funded project at the University of California, Santa Barbara, Eucalyptus Systems launched in April with funding from Benchmark Capital and BV Capital	Is commercializing an open-source platform for building private clouds using existing hardware and software, which can then be merged with a public cloud like Amazon Web Services. This hybrid approach allows companies to move data and applications in and out of the public cloud as the need arises.
Open Cirrus www.opencirrus.org	HP, Intel, Yahoo, University of Illinois at Urbana-Champaign, Karlsruhe Institute of Technology (Germany), Infocomm Development Authority (Singapore)	A test bed for researchers studying how to design and manage data centers for the cloud.
Google/IBM Cloud Computing University Initiative	University of Washington; Carnegie Mellon; MIT; Stanford University; University of California, Berkeley; University of Maryland	Gives academic researchers and students access to the sponsors' huge computing resources so they may experiment with the design and management of cloud applications and services.
Reservoir www.reservoir-fp7.eu	IBM, SAP, Sun Microsystems, Telefonica, University of Messina, University College of London, Umea University, Universidad Complutense de Madrid, University of Lugano, Thales Group, Elsag Datamat, CETIC	An EU-funded project that promotes research into creating a service-based online economy based on distributed computing in an open cloud.

Privacy Requires Security, Not Abstinence

PROTECTING AN INALIENABLE RIGHT IN THE AGE OF FACEBOOK.

By SIMSON GARFINKEL

I'd be a fool to include my Social Security number in this article: doing so would leave me vulnerable to all manner of credit fraud, scams, and even criminal arrest. All of this would surely happen because a few bad people would read the article, write down my SSN, and pretend to be me.

We know a lot more about the use and abuse of SSNs today than we did back in 2002. That was the year the California state legislature passed SB 1386, the first U.S. law requiring that consumers be notified when computer systems holding their personal information are "breached" or that information is otherwise compromised. Because of SB 1386, we learned in 2005 that ChoicePoint—a company most Americans had never heard of—had somehow sold detailed credit histories on more than 163,000 consumers directly to identity thieves (more than 800 people suffered direct losses as a result). And in 2007, we learned that identity thieves had broken into the computer systems of the discount retailer TJX and stolen more than 45 million credit-card numbers.

We've also learned that governments are equally bad at securing personal information, as demonstrated by the half-million records breached at the Oklahoma Department of Human Services, the eight million records reportedly exposed at the Virginia Department of Health Professions, and the 26.5 million records stolen (along with a laptop and portable hard drive) from a work-from-home employee of the U.S. Department of Veterans Affairs.

All these cases, and many more, paint a disturbing picture of what is really threatening privacy in America today.

Privacy matters. Data privacy protects us from electronic crimes of opportunity—identity theft, stalking, even little crimes like spam. Privacy gives us the right to meet and speak confidentially with others—a right that's crucial for democracy, which requires places for political ideas to grow and mature. Absolute privacy, also known as solitude, gives us to space to grow as individuals. Who could learn to write, draw, or otherwise create if every action, step, and misstep were captured, immortalized, and evaluated? And the ability to conduct transactions in privacy protects us from both legal and illegal discrimination.

Until recently, people who wanted to preserve their privacy were urged to "opt out" or abstain from some aspects of modern society. Concerned about having your purchases tracked by a credit-card company? Use cash. Concerned that E-ZPass records might be used against you in a lawsuit? Throw coins at that toll booth. Don't want to show your ID at the airport? Drive. Don't want your location tracked minute by minute? Turn off your cell phone. And be in a minority: faced with the choice of convenience or privacy, Americans have overwhelmingly chosen the former. Companies like TJX haven't even suffered from allowing their customers' personal data to be leaked.

Now, however, abstinence no longer guarantees privacy. Of course, it never really did. But until the past two decades it was always possible to keep some private information out of circulation. Today, although you can avoid the supermarket savings card, the market will still capture your face with its video cameras. You can use cash, but large cash transactions are reported to the federal government. You can try to live without the Internet—but you'll be marginalized. Worse, you won't be able to participate in the public debate about how your privacy is wasting away—because that debate is happening online. And no matter what you do, it won't prevent your information from being stored in commercial networked systems.

In this environment, the real problem is not that your information is out there; it's that it's not protected from misuse. In other words, privacy problems are increasingly the result of poor security practices. The biggest issue, I've long maintained, is that decision makers don't consider security a priority. By not

Illustration by ISTVAN BANYAI


Your INTERNET PRIVACY®
WGW

insisting on secure systems, governments and corporations alike have allowed themselves to get stuck with insecure ones.

Consider the humble Social Security number. As a privacy advocate, I always chafe when people ask me for my "social." As a security professional, I am deeply disturbed that a number designed as an *identifier*—for the single specific purpose of tracking individuals' earnings to calculate Social Security benefits—has come to be used as a *verifier* of identity for countless other purposes. Providing my SSN should not "prove" that I am who I say I am any more than providing my name or address does. But in the absence of any better system, this number has become, in the words of Joanne McNabb, chief of California's Office of Privacy Protection, the "key to the vault for identity thieves."

Yes, privacy as we know it is under attack—by a government searching for tax cheats and terrorists; by corporations looking for new customers; by insurance companies looking to control costs; and even by nosy friends, associates, and classmates. Collectively, we made things worse by not building strong privacy and security guarantees into our information systems, our businesses, and our society. Then we went and networked everything, helping both legitimate users and criminals. Is it any wonder things turned out this way?

All of a sudden, we have a lot of work to do.

But while our current privacy issues feel as new as Twitter, the notion of privacy as a right is old. Americans have always expected this right to be maintained, even as technology opened ever more powerful tools for its subversion. The story of privacy in America is the story of inventions and the story of fear; it is best told around certain moments of opportunity and danger.

THE CONSTITUTION

The word *privacy* doesn't appear in the U.S. Constitution, but courts and constitutional scholars have found plenty of privacy protections in the restriction on quartering soldiers in private homes (the Third Amendment); in the prohibition against "unreasonable searches and seizures" (the Fourth Amendment); and in the prohibition against forcing a person to be "a witness against himself" (the Fifth Amendment). These provisions remain fundamental checks on the power of government.

Over time, however, the advance of technology has threatened privacy in new ways, and the way we think about the concept has changed accordingly.

Back in 1890 two Boston lawyers, Samuel Warren and Louis Brandeis, wrote an article in the *Harvard Law Review* warning that the invasive technologies of their day threatened to take "what is whispered in the closet" and have it "proclaimed from the house-tops." In the face of those threats, they posited a direct "right to privacy" and argued that individuals whose privacy is violated should be able to sue for damages.

Warren and Brandeis called privacy "the right to be let alone" and gave numerous examples of ways it could be invaded. After more than a century of legal scholarship, we've come to understand that these examples suggest four distinct kinds of invasion: intrusion into a person's seclusion or private affairs; disclosure of embarrassing private facts; publicity that places a person in a "false light"; and appropriation of a person's name or likeness.

In our world, "intrusions into a person's seclusion or private affairs" might describe someone's hacking into your computer system. Consider the case of Patrick Connolly, a U.S. military contractor accused of victimizing more than 4,000 teenagers by breaking into their computers and threatening to make their pictures and videos public unless they sent him sexually explicit photos and videos of themselves. You can also be intruded upon in many lesser ways: when companies force advertisements onto your screen, for example, or make pop-ups appear that you need to close. It's intrusive for a telemarketer to call you during dinner. That's why programs that block Internet advertisements and the federal government's "do not call" list are both rightly seen as privacy-protecting measures.

The desire to prevent the disclosure of embarrassing private facts, meanwhile, is one of the driving forces behind the privacy regulations of the Health Insurance Portability and Accountability Act (HIPAA). Because of this law and the regulations deriving from it, a health-care provider cannot disclose information in your medical records unless you give explicit permission. Another law, the Video Privacy Protection Act of 1988, makes it illegal for Netflix to disclose the movies you rent.

"False light" is a problem we still don't know how to address online. It's all too easy on today's Internet to attack a person's reputation with anonymously posted false statements. And even though free-speech advocates invariably say that the antidote to bad speech is more speech, experience has shown that this remedy is less effective in the age of Google. For example, two years ago AutoAdmit, an online message board for law students and lawyers, was sued by two female Yale Law students who said they'd been unable to obtain summer associate positions because vile and malicious sexual comments about them appeared whenever someone searched for their names.

Using a name or likeness without permission is at the heart of most "sexting" cases that reach the newspapers. Journalists often focus on the fact that teens are willingly sending sexy or downright pornographic photos of themselves to their boyfriends or girlfriends. But the real damage happens when a recipient forwards one of these photos to friends. That is, the damage is caused by the appropriation, not the receipt.

The fact that a dusty *Harvard Law Review* article corresponds so closely with the online privacy problems we face

today suggests that even though technology is a driving factor in these privacy invasions, it's not the root source. The source is what sits in front of the computer's screen, not behind it.

For another example, consider electronic surveillance. Although e-mail and telephones give the appearance of privacy, sensitive electronic communications have always been an attractive target. Wiretapping was employed by both sides during the Civil War, prompting some states to pass laws against it. But it was the invention of the microphone and the telephone that brought the possibility of electronic surveillance into the homes of ordinary Americans. This shifted the action in U.S. privacy law from information to communication.

In 1928, in a case called *Olmstead v. United States*, the Supreme Court heard the appeal of a Seattle bootlegger whose phones had been tapped by federal agents. The agents had not trespassed or broken any laws to install the wiretaps, but they didn't have a search warrant either, as would have been required for a physical search of Roy Olmstead's property.

Brandeis, who had been appointed to the court by Woodrow Wilson in 1916, was appalled. "Whenever a telephone line is tapped, the privacy of the persons at both ends of the line is invaded, and all conversations between them upon any subject, and although proper, confidential and privileged, may be overheard," he wrote in his opinion. Alas, it was a dissent. By a 5–4 majority, the court found in favor of the government: search warrants were not required for eavesdropping on electronic communications, because "there was no searching." Olmstead went to prison, federal agents got the right to wiretap without a warrant, and that's how the law stood for another 39 years, until the case was overturned by a more liberal court in 1967.

It's comforting to know that U.S. law eventually gets things right with respect to privacy—that is the power of our republic, after all. But it's also troubling how long it sometimes takes. A lot of injustice can happen while we wait for the law to accommodate advances in technology.

THE COMPUTER

Consumer data banks as we know them today—big repositories of personal information, indexed by name and specifically constructed for the purpose of sharing information once regarded as "private"—didn't start with computers. But computers certainly helped.

One of today's largest consumer reporting firms was started in 1899, when two brothers created the Retail Credit Company—now known as Equifax—to track the creditworthiness of Atlanta grocery and retail customers. Businesses were encouraged to report which of their customers reliably paid their bills and which did not. Retail Credit collected the information, published it in a book, and sold copies.

Retail Credit and other consumer reporting firms maintained paper files until the 1960s. When they finally started to computerize, they came head to head with a Columbia University political-science professor named Alan Westin.

Westin had uncovered countless cases in which people had been denied credit, insurance, housing, even jobs, because of errors in consumer files—records that many victims didn't even know existed. He feared that computerization would make credit data banks much more widely used, with ominous consequences unless they were properly regulated. In the computer age, he said, privacy is no longer just the right to be left alone; it involves people's right "to determine for themselves when, how, and to what extent information about them is communicated to others." Possession of personal information, Westin said, should not give corporations unlimited rights to use that information.

Westin's research sparked numerous congressional investigations and got him invited to testify before Congress. People were entitled to view their own records, he said. And they needed a way to dispute the records and force an investigation if they thought there was an error.

Retail Credit and others protested that they would be stymied and bankrupted by a flood of requests. And Westin's definition of privacy could put different parties' rights in clear conflict—taken to its extreme today, it would mean that an ex-lover could order you to remove his or her name from your address book and delete all those old e-mails. But Westin and the other privacy advocates won the day, and Congress passed the Fair Credit Reporting Act of 1970. A Nixon administration advisory committee then developed the Code of Fair Information Practice, a guiding set of principles that underlies the majority of U.S. privacy laws passed since.

This code is surprisingly straightforward. There should be no secret data banks; individuals must be able to view their records; there must be a way to correct errors; organizations maintaining data banks must make sure they're reliable and protect them from unauthorized access; and information collected for one purpose must not be used for other purposes.

For example, the Video Privacy Protection Act was passed after Judge Robert Bork's video rental records were obtained by the Washington, DC, weekly *City Paper* in an attempt to dig up embarrassing information while the U.S. Senate was debating his 1987 nomination to the Supreme Court. The Driver's Privacy Protection Act of 1994 was passed after actress Rebecca Schaeffer was murdered in 1989 by a crazed fan, who had hired a private investigator to track down her address. The investigator was able to get the information through the California Department of Motor Vehicles, which had required Schaeffer to provide her home address when she applied for a license.

In both cases, Congress acted to prevent personal information from being reused in certain ways without permission. Score two for the updated concept of privacy.

THE INTERNET

In the 1980s and early 1990s, while lawmakers in Europe and Canada passed comprehensive privacy legislation complete with commissioners and enforcement mechanisms, the United States adopted a piecemeal approach. Some databases had legally mandated privacy guarantees; others didn't. Wiretapping required a warrant—except when companies taped employees for the purpose of "improving customer service." But even if policies weren't consistent, they basically covered most situations that arose.

Then came the Internet's explosive growth—a boon to community, commerce, and surveillance all at the same time. Never before had it been so easy to find out so much, so quickly. But while most Internet users soon became dependent on services from companies like Yahoo and Google, few realized that they themselves were the product these companies were selling.

All activity on the Internet is mediated—by software on your computer and on the remote service; by the remote service itself; and by the Internet service providers that carry the data. Each of these mediators has the ability to record or change the data as it passes through. And each mediator has an incentive to exploit its position for financial gain.

Thousands of different business models bloomed. Companies like Doubleclick realized that they could keep track of which Internet users went to which websites and integrate this information into vast profiles of user preferences, to be used for targeting ads. Some ISPs went further and inserted their own advertisements into the user's data stream. One e-mail provider went further still: it intercepted all the e-mail from Amazon.com to its users and used those messages to market its own online clearinghouse for rare and out-of-print books. *Whoops*. That provider was eventually charged with violating the Federal Wiretap Act. But practically every other intrusive practice was allowed by the law and, ultimately, by Congress, which was never able to muster the will to pass comprehensive Internet privacy legislation.

It's not that Congress was shy about regulating the Internet. It's just that congressional attention in the 1990s was focused on shielding children from online pornography—through laws eventually found unconstitutional by the Supreme Court, because they also limited the rights of adults. The one significant piece of Internet privacy legislation that Congress did manage to pass was the Children's Online Privacy Protection Act (COPPA), which largely prohibited the intentional collection of information from children 12 or younger.

Instead, it fell mostly to the Federal Trade Commission to regulate privacy on the Internet. And here the commission used one primary tool: the FTC Act of 1914 (since updated), which prohibits businesses from engaging in "unfair or deceptive acts or practices." The way this works in connection with online privacy is that companies write "privacy policies" describing what they do with personal information they obtain from their customers. Companies that follow their policies are fine—even if they collect your information and publish it, sell it, or use it to send e-mail or for "any other lawful purpose" (and the law is pretty tolerant). The only way for companies to get in trouble is to claim that they will honor your privacy in a specific manner and then do something different.

Hearings were held at the end of the Clinton administration to pass some online privacy legislation with real teeth. I testified in favor of strong regulations at one of those hearings, but sitting next to me at the witness table were powerful business interests who argued that regulation would be expensive and hard to enforce. The legislation didn't go anywhere. Business groups saw this outcome as the triumph of their "market-based" approach: consumers who weren't happy with a company's privacy stance could always go elsewhere. Privacy activists winced, knowing that legislation would be unlikely to pass if the Republicans won in 2000. We had no idea how right we were.

9/11: THE FIRST NATIONAL SCARE OF THE COMPUTER AGE

The terrorist attacks of September 11, 2001, changed the terms of the debate. Suddenly, the issue was no longer whether Congress should protect consumer privacy or let business run wild. Instead, the question became: Should Congress authorize the Bush administration to use the formidable power of state surveillance to find terrorists operating inside the United States and stop them before they could carry out their next attack?

The administration itself had no doubts. Where laws protecting privacy got in the way of its plans to prevent attacks, it set out to change those laws. The pinnacle of this effort was the USA Patriot Act, signed on October 26, 2001, which dramatically expanded government power to investigate suspected terrorism. In the months that followed, representatives for the administration repeatedly denounced those who complained about threats to privacy and liberty; they were, said Attorney General John Ashcroft, "giv[ing] ammunition to America's enemies."

It was a strong, simple, and remarkably effective message—so effective that we know of only a few cases in which Congress pushed back. The first and most public such case involved a Department of Defense research project called Total Information Awareness (TIA).

Soon renamed Terrorism Information Awareness, TIA was the brainchild of the Defense Advanced Research Proj-

ects Agency's newly created Information Awareness Office, which was run by retired admiral John Poindexter (a former national security advisor) and his deputy, Robert L. Popp. The idea, which drew heavily on both men's earlier work in undersea surveillance and antisubmarine warfare, was to use new advances in data mining and transactional analysis to catch terrorists while they were planning their attacks.

One way to find submarines is to wire the ocean with listening sensors and then to try to filter the sounds of the sea to reveal the sounds of the subs. The terrorist problem is similar, Poindexter explained at the 2002 DARPATech conference. The key difference is that instead of being in an ocean of water, the terrorists were operating in an ocean of data and transactions. "We must find terrorists in a world of noise, understand what they are planning, and develop options for preventing their attacks," he said in his published remarks.

ordered the IRS to investigate his political opponents, including major contributors to George McGovern's presidential campaign. (Many believe that opposition to TIA was also a kind of payback against Poindexter, who had been convicted of lying to Congress in the Iran-Contra scandal of the 1980s but had his conviction overturned on appeal.) Congress defunded the program in 2003.

TIA was never more than a research project. But other initiatives were moving ahead at the same time.

For example, in 2002 officials from the Transportation Security Administration asked JetBlue Airways to provide detailed passenger information to Torch Concepts, a company in Huntsville, AL, that was developing a data mining system even more invasive than the one envisioned by DARPA. JetBlue was eager to help: five million passenger records were transferred. The records, which included passenger names,

> I believe that we will be unable to protect online privacy without a strong electronic identity system that's free to use and backed by the governments of the world—a true passport for online access.

The approach isn't so far-fetched. Consider that the 1995 Oklahoma City bombing used explosives made of fertilizer and fuel oil, delivered in a rented Ryder truck. One way to stop similar plots in advance might be to look for people other than farmers who are purchasing large quantities of fertilizers used in making bombs—with extra points if the person (or one of his friends) has also rented a moving truck.

That task will be made a bit easier when stores that sell ammonium nitrate are registered with the Department of Homeland Security (a federal law to that effect was passed in 2007). Still: even when we have such registration, the prevention of an attack using fertilizer will require real-time purchase information from every fertilizer seller in the United States.

While I was a graduate student at MIT during the summer of 2003, I got a job working on the TIA project, because I thought that data mining would be a way to objectively look through mountains of personal information without compromising privacy. Congress, however, opposed TIA on the grounds that it treated everyone in the country as a suspect, and because it feared that a massive data surveillance system might be used for purposes other than catching terrorists. This prospect was not so hypothetical: in 1972 Richard Nixon had

addresses, phone numbers, and itineraries, were then combined, or "fused," with a demographic database purchased from a marketing services company called Acxiom. That second database specified passengers' gender, income, occupation, and Social Security number; whether they rented or owned their home; how many years they had lived at their current address; how many children they had; how many adults lived in their household; and how many vehicles they owned.

Torch Concepts identified "several distinctive travel patterns" in the data and concluded that "known airline terrorists appear readily distinguishable from the normal JetBlue passenger patterns," according to a company PowerPoint presentation unearthed by travel writer and privacy activist Edward Hasbrouck and publicized by Wired News on September 18, 2003. A media uproar ensued, but a 2004 report from the Department of Homeland Security ultimately concluded that no criminal laws had been broken, because JetBlue provided the data directly to Torch and not to the federal government. (JetBlue did violate its own privacy policy, however.)

Another data fusion project launched in the wake of 9/11 was the Multistate Anti-Terrorism Information Exchange (Matrix), which was also shut down amid privacy concerns. According to

a report by the DHS Privacy Office, the system was designed to allow law enforcement agencies in different states to easily search one another's computers, although the system "was over-sold as a pattern analysis tool for anti-terrorism purposes." The report found that Matrix was late in forming its privacy policy and that it "lacked adequate audit controls." Public support fell off, states pulled out, and the project was terminated.

Since then, a number of states and cities have partnered with DHS to create so-called "fusion centers," with the goal of helping sensitive information flow between federal, state, and even local law enforcement agencies. There were 58 fusion centers around the country by February 2009, according to the department's website, and DHS spent more than $254 million to support them between 2004 and 2007.

Few details of what actually happens at these centers have been made public. But in April 2008, Jack Tomarchio, then the department's principal deputy undersecretary for intelligence and analysis, told the Senate Committee on Homeland Security and Governmental Affairs that information from two U.S. fusion centers had been passed to a foreign government, which set up a terrorism investigation as a result. "DHS received a letter expressing that country's gratitude for the information," he testified. "This information would not have been gleaned without state and local participation."

At least in the eyes of the Bush administration, sacrificing the privacy of Americans to the security of the country had proved well worthwhile. But now the pendulum is swinging back, showing once again that our republic values privacy and will act to protect it from abuses—eventually.

FACEBOOK

Here's a kōan for the information age: Why do so many privacy activists have Facebook pages?

Originally conceived as a place for Harvard undergraduates to post their photos and cell-phone numbers—information that Harvard, because of privacy concerns, wasn't putting online back in 2003—Facebook has grown to be the fourth-most-popular "website" in the world, according to the Web services firm Alexa. But Facebook is really a collection of applications powered by private information: a smart address book that friends and business contacts update themselves; a (mostly) spam-free messaging system; a photo-sharing site. And on Facebook, developers write seamlessly integrated applications.

These applications are troubling from a privacy perspective. Say you want to complete one of those cool Facebook surveys. Click a button and you'll be taken to a page with the headline "Allow Access?" Then you'll be told that using the application allows it to "pull your profile information, photos, your friends' info, and other content that it requires to work." How much information? There's no way to be sure, really—perhaps everything you've put into Facebook.

The roughly one in five Internet users who spend an average of 25 minutes each day on Facebook implicitly face a question every time they type into a Facebook page: Do they trust the site's security and privacy controls? The answer is inevitably yes.

That's the reason privacy activists are on Facebook: it's where the action is. It's easy to imagine a future where most personal messaging is done on such platforms. Activists and organizations that refuse to take part might find themselves irrelevant.

It was in a similar context that Scott McNealy, then CEO of Sun Microsystems, famously said, "You have zero privacy anyway. Get over it." In January 1999, McNealy was trying to promote a new technology for distributed computing that Sun had cooked up—an early version of what we might call "cloud computing" today—and reporters were pestering him about how the system would protect privacy. Four and a half years later, he told the *San Francisco Chronicle*, "The point I was making was someone already has your medical records. Someone has my dental records. Someone has my financial records. Someone knows just about everything about me."

Today it's not just medical and financial records that are stored on remote servers—it's everything. Consider e-mail. If you download it from Post Office Protocol (POP) accounts, as most Internet users still did in 1999, the mail is copied to your computer and then deleted from your ISP's servers. These days, however, most people use Web mail or the Internet Message Access Protocol (IMAP), which leaves a copy on the server until it is explicitly deleted. Most people don't know where that server is—it's just somewhere "in the cloud" of the Internet. *[Editor's note: see our Briefing on cloud computing, beginning on p. 53.]*

Services like Facebook, Gmail, and Google Docs are becoming wildly popular because they give users the freedom to access their data from home and from work without having to carry it back and forth. But leaving your data on some organization's servers creates all sorts of opportunities for mishap. The organization might have a bad employee who siphons out data for personal profit. Cyberthieves might break into its servers and try to steal lots of people's data at the same time. Or a hacker might specifically target your data and contact the organization, claiming to be you. All these are security threats—security threats that become privacy threats because it's *your data*.

WHERE WE ARE NOW

I have spent a good part of my professional life looking for ways to make computer systems more secure, and I believe that many of the problems we face today are not only tractable—many of them have already been solved. The threat of data theft by insiders can be mitigated by paying employees

enough, auditing their work, limiting the amount of authority that any one employee has, and harshly punishing any individual who abuses the employer's trust. Computer systems can be made immune to buffer-overflow attacks, one of the most common security vulnerabilities in recent years, by programming them in modern languages like Java and Python instead of 1980s standards like C and C++. We really do know how to build secure systems. Unfortunately, these systems cost more to develop, and using them would require us to abandon the ones we already have—at least for our critical applications.

But one fundamental problem is harder to solve: identifying people on the Internet. What happens if somebody impersonating you calls up a company and demands access to your data?

If Google or Yahoo were storefronts, they would ask to see a state-issued ID card. They might compare a photo of you that they took when you opened the account with the person now standing in their lobby. Yes, there are phony IDs, and there are scams. Nevertheless, identification technology works pretty well most of the time in the physical world.

It turns out that we essentially have the technology to solve this problem in the digital world as well. Yet the solutions that have been developed aren't politically tenable—not only because of perceived costs but also, ironically, because of perceived privacy concerns.

I understand these fears, but I think they are misplaced. When someone can wreak havoc by misappropriating your personal data, privacy is threatened far more by the lack of a reliable online identification system than it would be by the introduction of one. And it is likely that it would cost society far more money to live with poor security than to address it.

I believe that we will be unable to protect online privacy without a strong electronic identity system that's free to use and backed by the governments of the world—a true passport for online access. One of the fundamental duties of government is to protect the internal security of the nation so that commerce can take place. For hundreds of years, that has meant creating identification documents so that people can prove their citizenship and their identity. But the U.S. government has abdicated its responsibility in the online world, and businesses have made up their own systems—like asking for your Social Security number and address, and perhaps your favorite color.

The difficulty of identifying people in the electronic world is a problem for every single company, every single organization, every single website. And it is especially a problem for Facebook and Google, because at a very basic level, they don't know who their customers are. When you open an account at a bank, U.S. law requires that you prove your identity with some state-issued identification. Bank accounts are linked to an actual identity. But electronic accounts like those on Facebook and Google aren't. They *project* an identity, but they aren't linked, really, to anything. That's a real problem if some hacker takes over your Gmail account and you need to get it back.

One solution would be to make driver's licenses and other state-issued IDs usable online by adding electronic chips. Just imagine: no more passwords to access your bank account, to buy something at Amazon, or to bid on eBay. Just insert your card. And if you lost the card, you could report it missing and get a new one. Instantly, all your online accounts would recognize the new credential and refuse to honor the old one.

Similar proposals have been made in the past: in the 1990s the U.S. Postal Service began working toward a system called the "U.S. Card." But the project never really got off the ground—partly because the technology wasn't quite ready, but also because of significant public opposition. In fact, in the United States *every* attempt to improve identification credentials has provoked significant public opposition. Many privacy activists see mandatory ID cards as one of the hallmarks of a police state. And many state governments fear the costs.

Though a stronger identification system would undoubtedly harm some citizens through errors, I think the opposition is unfortunate. We're already being identified every time we use an online banking service, or make an online purchase, or even use Facebook. We're just being identified through ad hoc, broken systems that are easy for bad guys to exploit. If we had a single strong identity system, we could adopt legislation to protect it from inappropriate use. A California law enacted in 2003, for example, prevents bars, car dealers, and others from collecting information swiped from a driver's license for any purpose other than age verification or license authentication.

For more than 100 years, American jurisprudence has recognized privacy as a requirement for democracy, social relations, and human dignity. For nearly 50, we've understood that protecting privacy takes more than just controlling intrusions into your home; it also requires being able to control information *about* you that's available to businesses, government, and society at large. Even though Americans were told after 9/11 that we needed to choose between security and privacy, it's increasingly clear that without one we will never have the other.

We need to learn how to protect privacy by intention, not by accident. Although technology can help, my belief is that such protections need to start with clearly articulated polices. Just as Nixon created the Environmental Protection Agency to protect our environment, we need some kind of Privacy Protection Agency to give our rights a fighting chance. Our piecemeal approach is no longer acceptable. TR

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REVIEWS

ENVIRONMENT

Carbon Trading on the Cheap

CONGRESS IS DEBATING A CAP-AND-TRADE SYSTEM TO REDUCE CARBON DIOXIDE EMISSIONS. BUT EUROPE'S VERSION OF THE MARKET-BASED SCHEME HAS BEEN A FAILURE SO FAR.

By PETER FAIRLEY

Advocates of carbon-trading schemes in the United States like to point to Europe's cap-and-trade program as a model worthy of emulation. The European Union's Emission Trading System, which has been in place since 2005, puts a price on carbon dioxide pollution for the purpose of inducing industry to cut emissions of greenhouse gases and reduce the effects of climate change. European governments set annual caps on total carbon dioxide emissions that may be produced by a group of energy-intensive industries. They then hand out a number of allowances to each company, allotting them on the basis of past emissions. Each allowance, called an EUA, permits the company to release a ton of carbon dioxide into the atmosphere. Companies whose emissions exceed their allowances for a given year must buy more; those with fewer emissions can sell their allowances.

EUROPEAN UNION'S EMISSION TRADING SYSTEM

While other governments and authorities (including a consortium of U.S. states) are experimenting with carbon trading, Europe's system accounts for more than three-quarters of such trading on a global scale. The trade in EUAs has amounted to more than 140 billion euros ($196 billion). Yet Europe has vanishingly little to show for all this.

In theory, limiting the supply of the pollution allowances helps to establish a price for the emission of carbon dioxide. That, in turn, is meant to provide industrial manufacturers and power producers with financial incentives to develop cleaner technologies. The reality has played out very differently, however. A glut of pollution credits, distributed without cost during both the first, transitional phase of the program and the current working phase, drove down the value of the EUAs. As a result, Europe's carbon dioxide emissions remain priced well below 20 euros per ton. With the price of pollution so low, economists say, industries that generate and consume energy have no incentives to change their habits; it is still cheaper to use fossil fuels than to switch to technologies that pollute less.

"It is hard to tell if any investment decision in the last three to four years has really been shaped by the carbon price," says Sophie Galharret, an energy economist with the French-Belgian power utility GDF Suez and a research fellow studying European energy and climate markets at Sciences Po, France's elite university of political science and economics in Paris. "The perfect market should provide such incentives," says Galharret, "but today's real market does not."

Indeed, many doubt that Europe's trading scheme will drive innovation forward anytime soon. The European Union has vowed to cut greenhouse-gas emissions by at least 20 percent—relative to 1990 levels—by 2020. That translates into a 1.74 percent annual reduction in allowances available to companies covered by the trading system. But companies can easily meet the emissions goal without deploying new technologies. The trading rules allow the companies to receive "offsets" to their own pollution if they invest in projects that reduce or prevent greenhouse-gas emissions in developing countries outside the EU. The other half of the necessary reductions will be achieved if EU members make good on mandated increases in renewable energy. In other words, though the carbon market is described as the centerpiece of EU climate and energy policy, energy investors may ignore it for at least the next decade.

Such problems explain why, even as the United States looks to Europe for a market-based approach to controlling emissions, critics there are clamoring to further tighten the EU emission trading system, or to scrap the carbon market altogether.

WINDFALL PROFITS

Blame a combination of factors—bad information, the coddling of domestic industries, the recent economic downturn—for blunting the European Union's emission trading system.

EPANCHINCEV EVGENIY/ITAR-TASS/CORBIS

The European Commission proposed the carbon-trading scheme in late 2001 as a means of getting the European states to meet their commitment to reducing greenhouse-gas emissions under the Kyoto Protocol. Barely three years later, European countries had allocated EUAs to more than 11,500 power plants and industrial facilities such as steel mills, oil refineries, and cement works, representing close to half of European carbon emissions. Nearly all the EUAs, which were valid for a trial period running from 2005 to 2007, were handed out free of charge in order to short-circuit complaints from industry interests that the added cost of pollution permits would crimp their global competitiveness.

At first the trading system looked healthy; virtual trading pits such as the London-based European Climate Exchange thrived. Futures contracts on a 2007 EUA climbed steadily from about seven euros in January 2005 to more than 30 euros by April 2006. In 2005 alone, carbon exchanges traded 362 million EUAs with an estimated financial value of 7.2 billion euros, according to Oslo-based market consultancy Point Carbon.

Then, in May 2006, EUAs plummeted in value, to less than 15 euros. After recovering briefly in the summer of 2006, EUA futures settled at close to zero for the remainder of the trial phase. Emissions data released in May 2008 revealed that European states, relying on unreliable emissions estimates and under pressure from various industries, had handed out EUAs for 6,321 million tons of carbon dioxide during the first phase, exceeding total actual emissions during the period by 107 million tons.

Global recession is now undermining the second phase of the trading system, which started last year. The European Union set the cap for the 2008–2012 period at 6.5 percent lower than the cap for the trial period. Trading volumes initially exploded, according to Point Carbon. But the rally proved short-lived. The EUA price slid to an average of just 11 euros in the first quarter of 2009, as manufacturing slowed in the face of the recession.

The faltering trading scheme may be doing real harm. Free permits and weak carbon pricing have rewarded the heaviest carbon polluters while hurting Europe's consumers. Most EU states gave extra allowances to heavy industries such as cement and steel, because they didn't want to threaten the manufacturers' international competitiveness; by the same logic, states gave relatively few allowances to producers of electricity, a commodity that must be generated close to consumers and thus is not forced into global competition.

This allocation strategy means that electricity consumers have felt the brunt of the price increases. Power producers jacked up the price of electricity to cover the anticipated costs of their allowances. Power companies also add a theoretical "opportunity cost" to their consumers' bills for using the free EUAs they could have sold on the carbon market instead.

But consumers aren't the only ones penalized by the trading scheme and its process of handing out EUAs. Power producers using relatively clean technology are also suffering. Perversely, coal-heavy utilities with the highest emissions benefit the most from carbon trading, since most states allot them more EUAs. This gives them an unfair advantage over producers generating power with natural gas or renewable sources, which release less carbon.

In other words, many European power companies have seen windfall profits under cap-and-trade.

The trading system "increased the price of power, but [power producers] didn't face a real increase in their costs," explains Jos Sijm, a senior economist at the Energy Research Centre of the Netherlands. Sijm estimates that in markets such as the Netherlands, the U.K., and Germany, the trading system increased power prices by a "quite substantial" 4 to 10 euros per megawatt-hour in 2005 and 2006. "For the Netherlands it led to windfall profits on the order of 300 to 600 million euros," Sijm says. "For Germany, the amount of windfall profits would be much higher–a few billion euros."

It would be easier to accept the profit taking as an unfortunate transitional side effect of the trading scheme if the program achieved its goal of reducing carbon dioxide emissions. But teasing out the program's real impact on emissions is tough.

Emissions from power generation actually edged *up* by 1 percent over the previous year in both 2006 and 2007. Last year, emissions dropped by 3 percent, according to preliminary data released by the European Commission. But observers say the global economic recession probably accounts for most of that decrease. In any case, it is not likely that the trading system has prompted many technology changes. "If you really want to induce investments and major technological innovations, the price has to be higher and more stable," says Sijm.

IT WOULD BE EASIER TO ACCEPT THE PROFIT TAKING AS AN UNFORTUNATE TRANSITIONAL SIDE EFFECT OF THE TRADING SCHEME IF THE PROGRAM ACHIEVED ITS GOAL OF REDUCING CARBON DIOXIDE EMISSIONS. BUT TEASING OUT THE PROGRAM'S REAL IMPACT ON EMISSIONS IS TOUGH.

How much higher? Surveys of business leaders suggest that they will not seriously reconsider the way they use energy until the price of carbon exceeds 30 euros per ton. The late Dennis Anderson, a professor of energy and environmental studies at London's Imperial College, concluded in 2007 that significant change will come only when carbon prices "move to the upper end" of a range that he put at 40 to 80 euros per ton. Anderson estimated that the 40-euro threshold would have to be met to make onshore wind farms and nuclear power a better investment than natural-gas or coal-fired power plants, while prices would have to approach 80 euros to make carbon capture and storage worthwhile. Even higher prices would be needed to make solar and offshore wind economical.

Economists at the International Energy Agency have recently calculated that holding global warming to a reasonable level would require an annual investment of $1.1 trillion per year. And it would require a $200 per ton price on carbon, said the IEA, to drive the necessary innovation.

RELUCTANT REFORMERS

Efforts to improve the EU trading scheme have been blunted by politics. Auctioning EUAs rather than giving them away would eliminate the windfall-profit taking and other perverse incentives wrought by free allocations. It would also generate revenues that some European countries promise to spend on alternative-energy R&D and energy-efficiency incentives, thus taking the sting from rising energy costs. But for the program's second phase, now in effect, less than 10 percent of the total number of allowances are available at auction. And the European Commission's proposal to auction all EUAs to power producers by 2013 took a hit when fast-growing, coal-dependent states such as Poland insisted on phasing in their auctions through 2020. Similarly, auctioning will phase in more slowly for those industrial sectors at greatest risk of competition from manufacturers outside the EU.

Meanwhile, politicians also opened the door wider to so-called carbon offsets, which allow companies to meet their emissions-reduction commitments by financing rain-forest conservation, renewable-energy investments, and other low-carbon projects in developing countries.

European industrialists argue that offsets make both economic and environmental sense, since climate change is global. The problem is that to the extent that offsets slacken demand for EUAs, they weaken the price signal that the carbon market is supposed to send to investors in Europe's energy sector and industries. The price signal will be further compromised by a new mandate, endorsed by European leaders in December, that requires 20 percent of Europe's energy production to be met through renewable sources by 2020.

No surprise, then, that some economists, as well as some experts in the power industry, advocate making adjustments to the emission trading system. Corrective measures under debate include a lower cap, tighter limits on offsets, or even a mandated floor price. Whatever the solution, many argue that the trading system will need to be significantly strengthened. "The ETS is not as tough as it needs to be," says Michael Grubb,

a visiting professor of climate change and energy policy at Imperial College and chief economist at the U.K. Carbon Trust, which advises business on low-carbon strategies.

What is especially disappointing is that even as the Europeans seek to undo many of the features that have made their carbon-trading system weak and dysfunctional, legislators in Washington seem determined to repeat their mistakes. Representatives Henry Waxman (D-CA) and Edward Markey (D-MA) introduced energy legislation built around a cap-and-trade system this spring, with the same concessions to carbon-intensive industries that neutralized the EU's trading system.

The U.S. bill, as it stood at press time, proposes to cut emissions to 17 percent below 2005 levels by 2020—essentially taking the U.S. back to (rather than much below) 1990 levels. And, as with Europe's trading system, a mix of offsets and renewable-energy mandates threatens to further undermine the carbon price. Analysts project U.S. carbon prices at a meager $15 to $20 per ton in 2020—barely a 10th of the price called for by the IEA.Most allowances, meanwhile, will be distributed without charge, despite the risk of windfall-profit taking and perverse market incentives. That move will also deprive President Barack Obama of revenues needed to fund the $150 billion, 10-year program of clean-energy R&D outlined in his 2010 budget proposal.

The prevailing wisdom among supporters of the Waxman-Markey bill is that Congress, wary of putting energy-intensive industries at risk, won't pass anything stronger. Best to get a carbon price established in the U.S. economic system now, supporters say, and tighten the system later. But this cap-and-trade scheme could be weak enough to send a dangerously *wrong* signal to financial markets looking to invest in new energy technologies. If you have any doubts about that, just take a look at the EU. TR

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MARC ROSENTHAL

MEDICINE

A Pound of Cure

THE FEDERAL GOVERNMENT HOPES THAT DIGITIZING MEDICAL RECORDS WILL REDUCE EXPENSES AND SHIFT MEDICINE'S FOCUS FROM TREATMENT TO PREVENTION. THERE'S JUST ONE PROBLEM: THE HEALTH-CARE INDUSTRY ISN'T PAID TO IMPROVE HEALTH.

By ANDY KESSLER

Technology is once again being touted as a cure-all, this time for what ails the American health-care industry. The Obama administration's $787 billion stimulus plan includes $19 billion for health-care IT spending that provides incentives for doctors and hospitals to adopt electronic health records. Starting in 2011, stimulus funds will provide additional Medicare and Medicaid reimbursements for health-care providers using such systems.

STIMULUS FUNDING FOR ELECTRONIC HEALTH RECORDS

These federal funding programs assume that the critical hurdle to widespread adoption of electronic medical records is cost. Indeed, hospitals surveyed in a study published last year in the *Journal of the American Medical Association* reported cost as the major barrier. Yet compared with other businesses, the health-care industry has been unmoved by the logic of lowering costs to increase profits. The truth is that these folks could have digitized the whole industry ages ago. The technology has been around for a long time: Wall Street began phasing out physical stock certificates over 35 years ago. Even the cash-strapped airline industry has gone ticketless, removing huge labor and overhead costs. These industries started using electronic records because they believed it would save money. The health-care industry simply has not followed suit.

The reason lies neither with cost nor with inadequate technology. Rather, the health-care industry's reluctance to digitize its records is rooted in a desire to keep medicine's lucrative business model hidden. Dangling $19 billion in front of a $2.4 trillion industry is not nearly enough to get it

to reveal the financial secrets that electronic health records are likely to uncover—and upon which its huge profits depend. In those medical records lie the ugly truth about the business of medicine: sickness is profitable. The greater the number of treatments, procedures, and hospital stays, the larger the profit. There is little incentive for doctors and hospitals to identify or reduce wasteful spending in medicine.

The amount of unnecessary spending is huge. In a project that analyzed 4,000 hospitals, the Dartmouth College Institute for Health Policy and Clinical Practice estimated that eliminating 30 percent of Medicare spending would not change either access to health care or the quality of the care itself. The Congressional Budget Office then suggested that $700 billion of the approximately $2.3 trillion spent on health care in 2008 was wasted on treatments that did not improve health outcomes. This excessive spending has kept the entire health-care industry growing faster than the population, and faster than inflation, for decades.

While electronic medical records do have sizable up-front costs, they also have the potential to save big, in part by streamlining administrative costs. According to a 2003 article by Dr. Steffie Woolhandler in the *New England Journal of Medicine*, administration accounts for 31 percent of expenses in the U.S. health-care industry, or more than $500 billion per year. (To put that in perspective, Google has spent well under 10 percent of that on all its R&D.) Richard Hillestad of the Rand Corporation wrote in *Health Affairs*, in 2005, that health-care information technology could save physicians' offices and hospitals more than $500 billion over 15 years thanks to improvements in safety and efficiency.

Electronic medical records would make it much easier to conduct the studies needed to track down this wasteful spending. According to one estimate, only about 4 percent of U.S. hospitals use comprehensive electronic record systems; most rely on paper records. As a result, analyzing the effectiveness of specific treatments—for example, spinal-fusion surgery versus physical therapy for back pain caused by a herniated disc—is unnecessarily expensive and time consuming. Physicians must compile data for a significant number of patients undergoing each treatment and correlate that information with each patient's outcome.

Using electronic health records, in combination with data mining and search technology, would make this kind of analysis much easier. Patients who fit specific criteria could be identified and tracked automatically, for example. Researchers would be able to analyze larger numbers of patients and a wider variety of treatments. With easy access to this kind of information, wasteful spending could be identified more readily, allowing payers, whether Medicare or private insurers, to stop reimbursing for expensive but unnecessary tests and procedures.

An even bigger threat to the sickness industry's business model is that by allowing automated tracking of patients over time, electronic health records would set the stage for early detection and preventive medicine. Currently, the entire industry is organized around treating sickness, rather than keeping people healthy in the first place. Three-quarters of health-care spending is devoted to chronic care, but the National Cancer Institute and the Centers for Disease Control and Prevention allot just 12 percent of their budgets to research on early detection. Moreover, the payment system is structured around reimbursement for treatment rather than prevention.

With widespread use of electronic health records, it would be easier to expand preventive medicine, not only by educating patients about lifestyle changes but also by conducting mass screenings. A recent American Cancer Society study concludes that prevention, early detection, and better treatment decreased cancer death rates between 1990 and 2005 by 19 percent for men and 11 percent for women. I would like to see funding for technologies that could ultimately improve early detection. Studies are now being launched on CT scans that can evaluate a patient's heart in less than one heartbeat. They produce finer resolution than existing technologies and return fewer false positives. These tests cost $1,000 now, but within five years, thanks to expected advances in computing power, we should see a $200 CT scan to detect heart disease *before* a heart attack.

BY ALLOWING AUTOMATED TRACKING OF PATIENTS OVER TIME, ELECTRONIC HEALTH RECORDS WOULD SET THE STAGE FOR EARLY DETECTION AND PREVENTIVE MEDICINE. THESE ARE THE REAL THREATS TO THE SICKNESS INDUSTRY'S BUSINESS MODEL.

The ability to detect cancer early enough and cheaply enough for effective treatment would prove much more cost effective than the current approach, which involves spending hundreds of thousands of dollars to extend the life of a cancer patient for a few months—generally, with low quality of life.

As valuable as electronic health records are for streamlining costs, their biggest contribution will lie in moving medicine toward early detection. Let's hope that the adoption of this screening technology is not postponed as long as electronic medical records have been, in a misplaced desire to protect the lucrative status quo. Like all good technology, it's probably going to get off the ground on the grassroots level. Expect your local Walgreens to promote these tests sooner than your doctor does.

ANDY KESSLER IS A WALL STREET ANALYST TURNED AUTHOR, MOST RECENTLY OF *THE END OF MEDICINE*.

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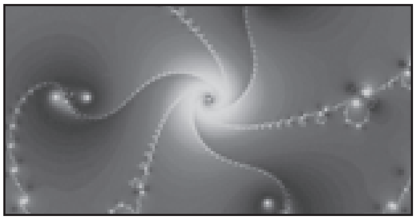

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Fractal: An infinitely repeating pattern

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HACK

A ACCELEROMETERS

An accelerometer rests just below each fingertip and on the back of the hand. When the user's hand moves, the accelerometers can detect the three-dimensional orientation of the fingers and palm with respect to Earth's gravity. Measured to within a few degrees, this information allows programs to distinguish even very slight changes in hand position.

AcceleGlove

OPEN-SOURCE DATA GLOVE CAN BE PROGRAMMED FOR MANY APPLICATIONS.

BY KRISTINA GRIFANTINI

GLOVES THAT ARE wired with sensors can provide useful information about a user's motions, and they offer a novel way to interact with computers beyond the keyboard and mouse. At the end of May, AnthroTronix, a company based in Silver Spring, MD, released its first commercial version of the AcceleGlove, a programmable glove that records hand and finger movements. Other gloves—like 5DT's Data Glove, used primarily in virtual reality—normally cost \$1,000 to \$5,000, but the AcceleGlove costs just \$499. It comes with software that lets developers use Java to program it for any application they wish. AnthroTronix initially developed the glove with the U.S. Department of Defense for robotic control. The glove could also be used in video games, sports training, or physical rehabilitation.

B DATA BOARD

The accelerometers feed the position information through lightweight copper wires to a printed circuit board, which sits on the back of the hand. When the user makes a gesture, such as pinching fingers together or holding the open palm outwards, the board transmits the data to a computer through a USB cord plugged in under a flap on top of the glove's wrist. The glove also receives its power through the cord, avoiding the need for a cumbersome battery pack.

BRUCE PETERSON

C GLOVE

Made of a breathable nylon mix that can stretch to fit hands of different sizes, the glove features open fingertips so a user can type or write while wearing it.

PROGRAMMING

AnthroTronix has created development software that lets users adapt the glove to new purposes. The user builds the glove's capability by recording a gesture and assigning a meaning to it; the program can store hundreds of gestures. The sensitivity with which the computer recognizes gestures can be varied, so it might recognize sloppy, large gestures for an application such as a children's educational program, or very precise gestures for robotics. The system can also accept data from two gloves worn simultaneously.

D ARM TRACKER

The glove can track the movement of the user's arm through an optional component. The arm link consists of two pieces of stretchy fabric, connected by a thin microcontroller, that wrap below the elbow and around the biceps. A potentiometer measures how the elbow flexes, and an accelerometer in the band around the biceps measures the rotation of the arm. The arm link also calculates the location of the wrist with respect to the shoulder, identifies where the wrist is with respect to the rest of the body, and records its movements. This precise measurement allows a user to monitor a football throw or manipulate a robotic arm, for example. The arm tracker plugs in under the same flap in the glove as the USB cord.

APPLICATIONS

Users don't have to tie themselves to the types of gestures that AnthroTronix's program can understand. While movements of the whole hand through space (such as waving) aren't recognized by the current software, the glove records raw data that a user could access and analyze using a specialized program such as Mathematica. Users could also write their own software to recognize such gestures, and AnthroTronix plans to release a future version of the developer's kit that will recognize them.

WWW See AnthroTronix CTO Jack Vice demonstrate the glove: **technologyreview.com/hack.**

DEMO

Building NASA's Future

THE U.S. SPACE AGENCY READIES THE FIRST TEST FLIGHT OF THE VEHICLE DESTINED FOR THE MOON.

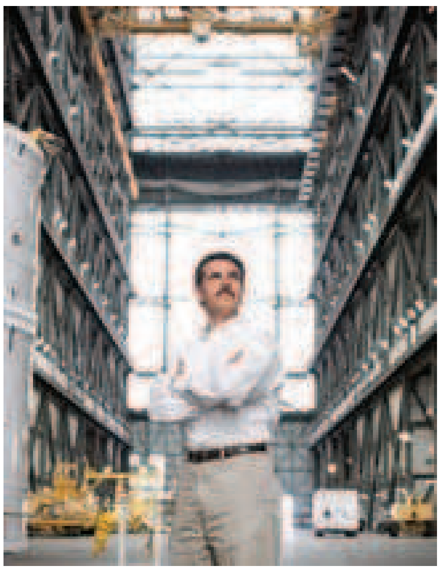
BY BRITTANY SAUSER

1

One of the largest structures in the world, the vehicle assembly building at Kennedy Space Center in Florida is the last stop for the space shuttle before it is rolled out to the launch pad. But with the shuttles scheduled to retire in 2010, the massive building has already become home to NASA's next launch vehicle.

The Ares rockets are a crucial part of the Constellation program, NASA's plan for new manned flights to the moon and possibly to Mars and beyond. Unlike its predecessors, the Ares will use separate launch vehicles to transport cargo and crew. Ares I will carry humans to space, while Ares V will transport large-scale hardware such as items needed to establish a lunar base.

Ares I-X, the first launch vehicle to be tested in nearly four decades, sits in immense pieces in the assembly building, awaiting a test flight scheduled for late August. "This flight will allow us to nail down the design of Ares I and eliminate uncertainties, so that everyone will feel more comfortable when the first rocket flies with humans on it," says Jon Cowart, deputy manager for the Ares I-X project at Kennedy. The main goal is to gather data during the first two minutes of ascent, when the rocket is most vulnerable to failures. To that end, the I-X includes a mix of real and simulated systems and is equipped with around 700 sensors that will measure load, pressure, vibration, temperature, acoustics, strain, and movement at different points on the rocket and at different stages of flight. The sensors will gather information on the rocket's performance in the roughest parts of the atmosphere, on the separation of its stages, and on the recovery of its boosters.



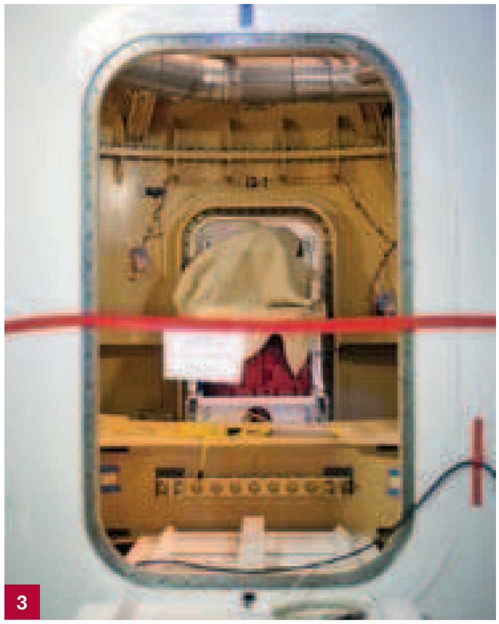
JOHN LOOMIS

IN PIECES

Entering High Bay 4 is like walking into a giant indoor stadium. In the middle of the bay sit five large steel cylinders, called stacks,


2

Bottom left: Jon Cowart, deputy manager for the Ares I-X, stands in the vehicle assembly building at Kennedy Space Center.
1. Steel pieces that make up most of Ares I-X are clustered in High Bay 4 of the assembly building. The five cylinders represent the interstage and upper stage of Ares I; the final piece is the dart-shaped mock-up of the crew capsule.
2. Since this first test flight of Ares I will not reach orbit, the fifth segment of the vehicle's rocket booster isn't needed. Engineers created a dummy version of the segment, which will hold the avionics module that guides the rocket's flight.
3. A system designed to control rotational forces on the rocket lies under a blanket that is visible through a hatch in the interstage.


3

that will be assembled into Ares I-X. Surrounding them is a seemingly haphazard assortment of cranes, toolboxes, laptops, and rolling chairs.

The first stage of Ares I will include a single, five-segment solid rocket booster. Its design is derived from the shuttle, which uses two four-segment solid rocket boosters, and it will burn the same specially formulated propellant. "We didn't want to start over," says Steve Cook, manager of the Ares project office at NASA's Marshall Space Flight Center in Huntsville, AL. "We took the best from the past and combined it with modern technology." Ares I-X will use only a four-segment reusable solid rocket booster, with a dummy fifth segment stacked on top. The mock segment marks the beginning of the first stack and lies in several similarly sized pieces, all solid white. (The fifth rocket motor will allow Ares I to lift more weight and reach a higher altitude, but it's not needed for the test flight.)

Near the bottom portion of the fifth-segment simulator is the first-stage avionics module, which will control the components of the booster and communicate with the upper stage. For example, the module will send the signal to fire the motors, control the vehicle's

4. Ares I-X has more than 700 sensors that will measure temperature and multiple forces on the rocket during all phases of its flight; some of the most critical sensors, such as those that gauge air pressure and speed, are at the top of the dart-shaped fifth stack, near the simulated rocket nozzles of the launch abort system.
5. Wires run down the walls of the simulated crew module; when the rocket is finished, they will connect sensors in the module to data recorders that reside in the avionics module (not shown).
6. A yellow framework known as the "birdcage" surrounds and supports the fifth stack as massive cranes lift it and mate it with its counterpart cylinder. It will take weeks for engineers to stack the rocket's pieces together. When fully assembled, Ares I-X will stand 99 meters tall and vary from 3.7 to 5.5 meters in diameter; it will weigh more than 800,000 kilograms when fueled.

flight path by moving the motor nozzle, initiate the booster separation sequence, and command the parachute recovery system. The module will also gather important test flight data, specifically on the performance of the flight control system. In the final design, however, the avionics will be housed in the upper stage of the rocket, since propellant will fill the fifth segment.

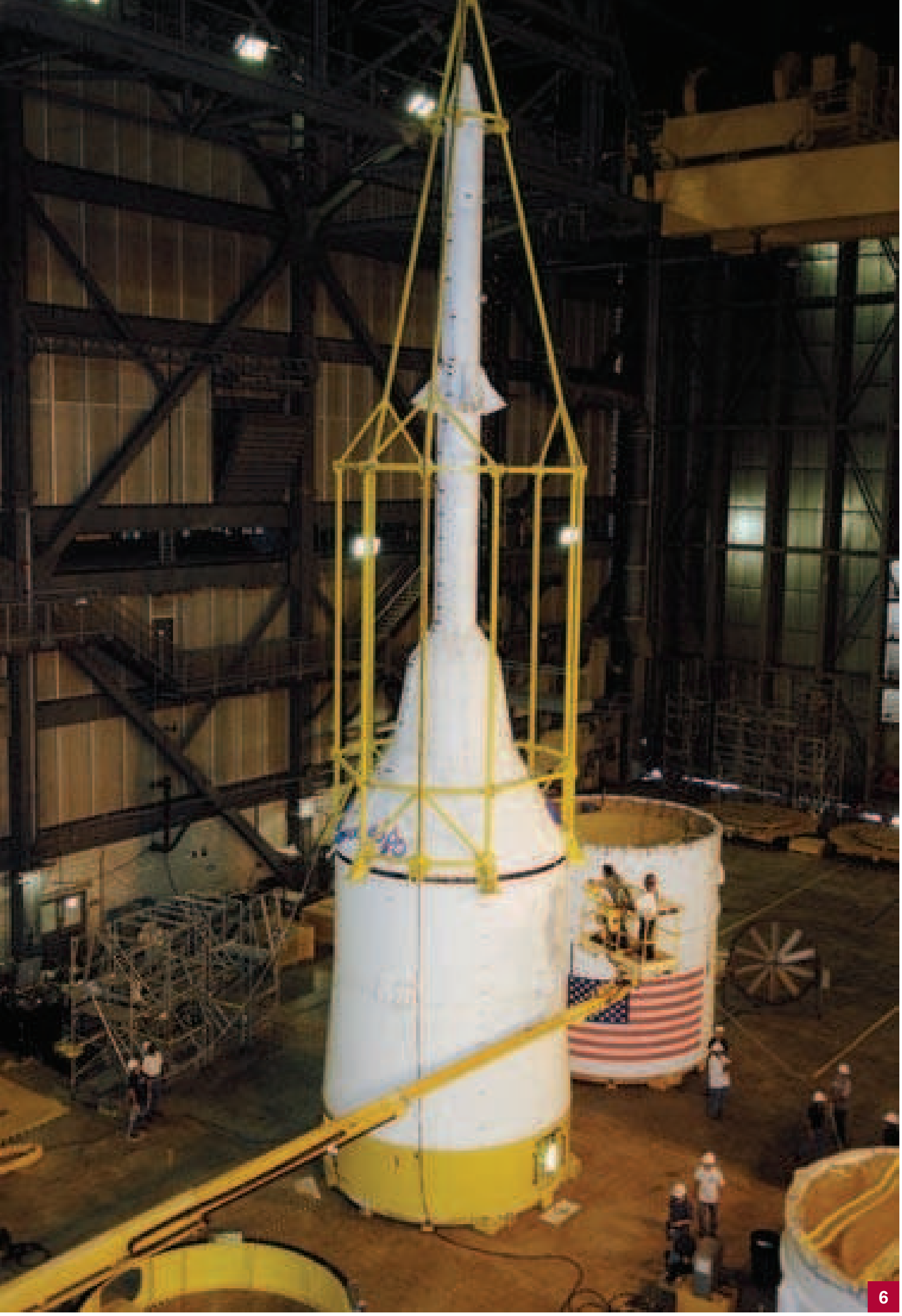
Mounted on top of the fifth-segment simulator are the forward skirt and its extension, which hold the parachute recovery system; it will allow the first stage, after breaking away from the upper stage, to safely splash down in the ocean, where it can be recovered for reuse. The system consists of a computer that triggers separation, a small explosive charge that cuts the metal, and five parachutes.

WWW See video of Ares I-X being built: **technologyreview.com/demo**

Ares's boosters are heavier than the space shuttle's boosters and will drop from a higher altitude, so they will be falling faster. To compensate, the launch vehicle's parachutes are much larger and stronger but, thanks to new materials, lighter. The parachutes will deploy in three stages, starting when the rocket boosters reach an altitude of about 4,500 meters. The staged deployment will not only slow the boosters for splashdown but also maneuver them into the appropriate position to prevent damage.

At the very top of the 24-meter-tall stack rests the interstage, which marks the beginning of the upper stage and holds the system designed to control the forces that cause the rocket to rotate during flight. The interstage of

JOHN LOOMIS



6

NASA

Ares I will also carry the rocket's J-2X engine, which will power the upper stage; it will not be simulated for the test flight, though its weight is accounted for.

The next three stacks simulate the shape and weight of the rest of the upper stage. Stack two, which is the shortest, represents the liquid oxygen tank. Engineers used steel ballast plates to account for the fuel's weight. Stack three, which is almost 14 meters tall, sports the NASA logo and three emblems that identify the mission. For the test flight, this stack is purely structural and will remain empty. In Ares I, however, it will house most of the liquid hydrogen tank, as well as the flight computer and avionics that control all aspects of flight. Stack four, which displays the U.S. flag, stands for the rest of the hydrogen tank, which will span both stacks; it is also filled with steel ballast plates.

The final stack of Ares I-X is the dart-shaped mock-up of the Orion crew module and launch abort system. The upper stage and crew module will make up a quarter of the assembled rocket's height; for the Ares I-X flight, it will carry many of the most critical sensors. However, after separation the engineers will have gathered the data they need most, so these portions will fall uncontrolled and splash into the Atlantic Ocean.

SOME ASSEMBLY REQUIRED

Inside the assembly building, Ares I-X will come to life. By the time they finish, engineers will have spent several weeks stacking the rocket's components, delicately maneuvering one piece on top of another with massive cranes. The completed Ares I-X will be nearly identical to Ares I from the outside: a sleek, two-stage rocket with the crew module on top, as far away from the propulsion system as possible. To make the test-flight data as accurate as possible, it will also be similar in mass and size, standing approximately 99 meters tall, varying from 3.7 to 5.5 meters in diameter, and weighing about 816,000 kilograms when fully fueled.

Three more unmanned test flights are planned after the August launch. Ares I-Y will be identical to the final rocket—nothing simulated—and is tentatively scheduled for launch in 2013. The Orion 1 and 2 launches, designed to test the crew module, are planned for the following year, and the first manned launch of Ares I is set for 2015.

NASA is staking its future on long-term exploration, moving beyond low Earth orbit and using the Ares rockets to get there. "The space shuttle has been a great machine, but we need a vehicle [with] better safety and reliability, and with more capabilities," says Cook. Ares I will have greater range than the shuttle and will cost less to maintain and launch, he says, so it will be possible to venture farther into space, and more often. When Ares V is completed, NASA hopes to build an outpost on the moon, sustaining a human presence there by 2020. The base will allow them to research and test new technologies useful for manned exploration of Mars. Says Cook, "This is what we came to NASA to do." TR

FROM THE LABS

BIOMEDICINE

Artificial Proteins

A SYNTHETIC PROTEIN BUILT FROM SCRATCH CAN CARRY OXYGEN, MIMICKING BLOOD

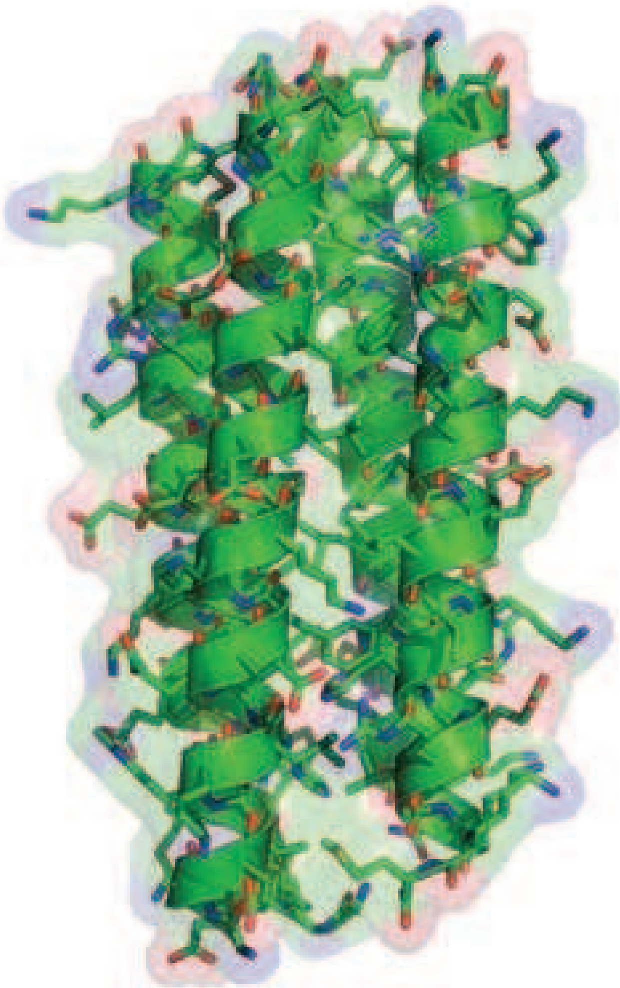
SOURCE: "DESIGN AND ENGINEERING OF AN O(2) TRANSPORT PROTEIN"
P. Leslie Dutton et al.
Nature 458: 305–309

Results: Scientists at the University of Pennsylvania have designed and built a protein that can transport oxygen. The protein is much simpler than the oxygen-carrying proteins found in nature, and the process that they used demonstrates a new method for making novel proteins.

Why it matters: A more complex version of the protein could eventually be used to create artificial blood. The research also illustrates the effectiveness of the new design process, which could be used to engineer other proteins that improve on the efficiency of important biological functions—or proteins with entirely new functions.

Methods: The design process begins with a simple artificial protein that the researchers gradually change until it performs a desired function. To make the oxygen-binding protein, the researchers used three amino acids, the building blocks of proteins, to create four novel helix-shaped structures that they assembled into a bundle. Then they replaced some of these amino acids with ones that would help the bundle incorporate a chemical group called a heme, which can bind oxygen molecules. They added other amino acids to help make the protein structure flexible enough to open, letting the heme bind oxygen, and then close, protecting the oxygen from water.

Next steps: Researchers plan to engineer artificial functional proteins that incorporate light-harvesting pigments to capture solar energy.



BETTER BY DESIGN
Four helices form the backbone of a man-made protein.

DUTTON LAB

Better MRI

A NEW METHOD OF MODIFYING MOLECULES COULD IMPROVE MEDICAL IMAGING

SOURCE: "REVERSIBLE INTERACTIONS WITH PARA-HYDROGEN ENHANCE NMR SENSITIVITY BY POLARIZATION TRANSFER"
Simon B. Duckett et al.
Science 323: 1708–1711

Results: A novel method of modifying the magnetic properties of molecules, developed by researchers at the University of York, in the United Kingdom, makes magnetic resonance imaging (MRI) a thousand times more sensitive. The technique provides a way to use a broad range of drugs and antibodies to label specific tissues for medical imaging.

Why it matters: If proved safe and effective in humans, the new technique would lead to new diagnostic and treatment applications for MRI. An antibody designed to stick to a tumor could be used for cancer screening, for example.

Methods: Researchers have known that hydrogenation reactions can be used to modify molecules with a form of hydrogen called parahydrogen, which changes their magnetic properties in a way that greatly improves MRI results. But this process works with only a few types of molecules. The researchers developed a way to temporarily link the parahydrogen to various organic molecules using an intermediary chemical complex, without causing them to undergo any chemical change. They showed that

the process enhances the magnetic signal of a variety of organic molecules, including chemicals widely used in making pharmaceuticals.

Next steps: The researchers aim to use the technique to perform MRI scans on animals later this year.

INFORMATION TECHNOLOGY

Social Security

RESEARCHERS RAISE PRIVACY CONCERNS ABOUT SOCIAL-NETWORK DATA

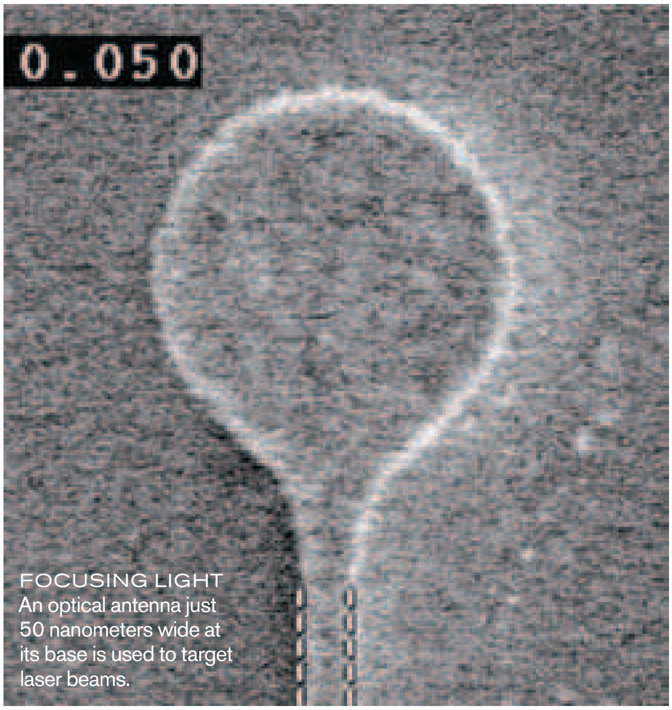
SOURCE: "DE-ANONYMIZING SOCIAL NETWORKS"
Arvind Narayanan and Vitaly Shmatikov
IEEE Symposium on Security and Privacy, May 17–20, 2009, Oakland, CA

Results: Researchers from the University of Texas at Austin designed an algorithm that can identify individuals using supposedly anonymous information that social-networking websites could provide to advertisers. In tests using Flickr and Twitter, they were able to assign names to a third of the users who maintained accounts on both sites, with only a 12 percent error rate.

Why it matters: Most social networks plan to make money by sharing data with advertisers. Although personally identifying information such as names and addresses is removed, the new study shows that individuals can still be identified.

Methods: The researchers developed an algorithm that compares publicly available information from one social-networking site—such as a person's name and list of contacts—with the data that another site might supply to advertisers. The publicly available data is used to help create a map of connections between people. The advertisers' data is used to create a similar map, with the names, addresses, and other personal information missing. The algorithm can identify features common to both that reveal a person's identity, even when the maps overlap by as little as 14 percent. The researchers designed the algorithm to start with social-network users who can easily be identified—as few as 30 individuals in 100,000—and then use personal information about those users to fill in details about others.

Next steps: Having demonstrated that the relationship information that makes social-network data useful could also compromise user privacy, the researchers say the solution is to change the privacy laws and corporate practices that govern the sharing of "anonymous" information from such sites.



FOCUSING LIGHT
An optical antenna just 50 nanometers wide at its base is used to target laser beams.

SEAGATE TECHNOLOGY/NATURE PHOTONICS

More Memory

A NEW DEVICE USES HEAT TO FIT EXTRA BITS ON A HARD DISK

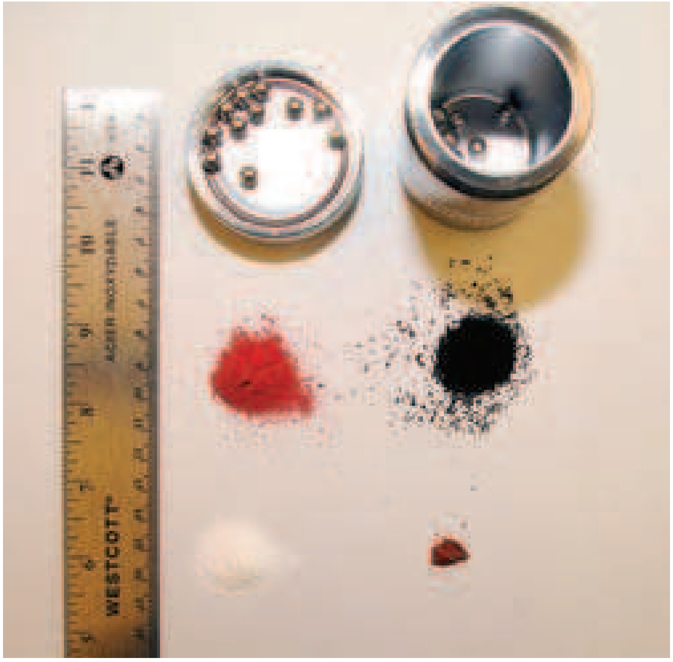
SOURCE: "HEAT-ASSISTED MAGNETIC RECORDING BY A NEAR-FIELD TRANSDUCER WITH EFFICIENT OPTICAL ENERGY TRANSFER"
William Challener et al.
Nature Photonics 3: 220–224

Results: Researchers at Seagate have developed a way to deliver targeted pulses of heat to the magnetic areas of hard-disk drives. The technology should make it possible to write up to 20 times more data to disks than is possible today.

Why it matters: Hard drives record data when a magnetic head moves across a disk coated with small grains that represent *1*s or *0*s, depending on their magnetic orientation. To cram more data onto these drives, researchers have been making the grains smaller and smaller. But grains made of conventional materials will become unstable if they're too small, losing data when they experience small fluctuations in temperature. The new recording method allows the researchers to use materials that are more stable, packing more bits into a given area to increase data storage capacity. In addition to holding more data, the resulting hard drives could be more reliable.

Methods: Today's magnetic heads can't write data to the more stable recording media. Heating the grains solves this problem, but it's been difficult to heat an area small enough to keep surrounding grains from being affected; no conventional lens can focus laser light onto such a tiny spot. The researchers accomplished this by focusing the light with a device called an optical antenna instead of a lens.

Next steps: The company hopes to reduce the concentrated spot of heat from 70 nanometers to 20 nanometers. The engineers are also developing a way to deliver laser light efficiently to the recording head.



CATALYST RECIPE Ball bearings help pack materials (red, white, and brown) into microscopic pores in carbon black (black).

MATERIALS

Cheaper Fuel Cells

AN INEXPENSIVE NEW CATALYST WORKS AS FAST AS PLATINUM

SOURCE: "IRON-BASED CATALYSTS WITH IMPROVED OXYGEN REDUCTION ACTIVITY IN POLYMER ELECTROLYTE FUEL CELLS"
Jean-Pol Dodelet et al.
Science 324: 71–74

Results: A catalyst made of iron, carbon, and nitrogen works nearly as well as platinum-based catalysts to accelerate the electrochemical reactions inside hydrogen fuel cells. The material produces 35 times as much current as previous catalysts not made of precious metals.

Why it matters: Hydrogen fuel cells for electric cars show promise because they emit no harmful pollutants, but they've been far too expensive to be practical. The new catalyst would greatly reduce the need for costly platinum in the fuel cells' electrodes, making the technology cheaper.

Methods: The researchers improved the performance of a catalyst they had previously developed, in which nitrogen atoms and an iron ion bridge tiny gaps formed in a carbon material to create active sites for catalysis. To increase the number of these active sites, the researchers used a commercially available type of carbon that contains a large number of microscopic pores, which they packed with a material containing nitrogen and iron. When the material is heated under certain conditions, the nitrogen and iron arrange themselves into the catalytic bridges.

Next steps: To be practical, the catalyst needs to become more durable; in the researchers' experiments, the reaction rates dropped by half after only 100 hours of testing. The reaction rates of the catalyst are also limited by how fast oxygen can move through the material to reach the active sites; this needs to be improved for the catalyst to work in fuel cells.

Bulk Graphene

SLICING CARBON NANOTUBES INTO RIBBONS MAKES SPEEDIER TRANSISTORS

SOURCE: "LONGITUDINAL UNZIPPING OF CARBON NANOTUBES TO FORM GRAPHENE NANORIBBONS"
James M. Tour et al.
Nature 458: 872–876

Results: Researchers at Rice University have developed a simple method for making large numbers of long, narrow ribbons of graphene, a single-atom-thick film of carbon. They chemically sliced open carbon nanotubes, which are essentially rolled-up sheets of graphene.

Why it matters: Graphene conducts electrons faster than silicon, so it could be used to make faster transistors. But it's been difficult to manufacture the semiconducting type of graphene that's needed for this application. One way to make semiconducting graphene is to cut the material into narrow nanoscale ribbons, typically a slow process. The new chemical method produces bulk quantities of these ribbons by modifying carbon nanotubes, which are easy to manufacture in large amounts. The approach also solves a problem with carbon nanotubes: their electronic properties can vary widely. Unzipping them to make nanoribbons makes these properties more uniform.

Methods: The researchers exposed multiwalled and single-walled carbon nanotubes to sulfuric acid and potassium permanganate, a strong oxidizing agent. The resulting reaction breaks a carbon-carbon bond in each nanotube, and the exposed carbon atoms immediately bind to oxygen atoms, creating a strain on the adjacent carbon-carbon bonds. This strain causes the adjacent bonds to break more easily, and a chain reaction propagates down the length of the tube, cleanly unzipping it into a ribbon. This reaction repeats on each of the nanotubes' walls, or concentric layers, yielding as many ribbons per tube as there are layers. The graphene nanoribbons must then undergo another reaction to remove the oxygen atoms. Finally, the researchers incorporated the nanoribbons into transistors using previously developed techniques.

Next steps: The researchers are developing thin-film and ink-jet printing methods for depositing nanoribbons, which would speed up the manufacture of graphene-based electronics such as radio-frequency identification tags. TR

SCIENCE/AAAS

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A Hard Sell

THE GREAT DEPRESSION OCCASIONED A BATTLE OVER FEDERAL FUNDING OF SCIENCE

By MATT MAHONEY

In the fall of 1933, with the United States in the depths of the Great Depression, Karl T. Compton, MIT's president and chairman of Franklin Delano Roosevelt's recently created Science Advisory Board, proposed allocating $16 million of the Public Works Administration's $3 billion budget to fund a "Recovery Program of Science." Its purpose would be to boost depleted research budgets and provide jobs for the legion of unemployed scientists and engineers. The funds were denied because no legislative authority existed for funding research through the PWA.

Undaunted, Compton spent the following year crafting a more ambitious proposal that would not only provide short-term relief to struggling scientists but also establish a national program for scientific research. Today, with the government committing tens of billions of dollars from its $787 billion stimulus package to funding basic science, and tens of billions more to get advanced technologies to market *(see "Chasing the Sun," p. 44)*, Compton's ideas seem relatively modest. But his efforts marked the beginning of a profound shift in the relationship between science and government, and in making the case Compton braved opposition on multiple fronts.

First, he faced a public skeptical of the distress cries coming from the professional class of scientists and engineers who had been flying high in the boom years of the 1920s. In fact, many believed that technology was largely to blame for the unemployment ravaging the country as machine labor replaced manual labor in industry. The public's indifference, if not its hostility, to science was echoed by cabinet members who failed to see much political or economic value in diverting resources to science.

Compton also had to deal with opposition from within his own camp. The older generation of scientific leaders, deeply committed to laissez-faire doctrines, feared that increasing the federal role in funding scientific research would result in greater federal interference with the scientific enterprise.

By the time Compton finally unveiled his proposal for a $75 million "Science Fund," it was already clear that the plan would go nowhere. Frustrated by Washington politics, Compton made his case publicly in an article called "Science Still Holds a Great Promise," published first in the *New York Times* and then, under a different title, in the January 1935 edition of *Technology Review*.

There are some striking anomalies in our national policy which suggest that an important prerequisite to sound and permanent economic recovery has thus far been neglected. I refer to the contributions to national welfare which may be expected of Science, if Science is really put to work.

It is well known that Science has created vast employment, yet it is not being called upon or encouraged now to create new employment when this is desperately needed! Perhaps this is because of a realization that time is necessary for the development of a scientific discovery into an operating industry, a time required for technical development and for "creating" the market. ...

A STIMULATING MAN Karl T. Compton,1935

Perhaps this neglect is a result of the early depression hysteria which, looking for a scapegoat, sought to place on "technology" the blame for the crash, forgetting that overproduction arises from competition for profits and not from science, that underconsumption arises from a paucity rather than a plethora of desirable products of science, that the labor-saving devices that spring from science are inherently desirable if used properly, and, most important of all, that the overwhelming influence of science has been to create employment, business, wealth, health, and satisfaction. ...

A colossal program of public works construction has been authorized, designed to give useful employment and at the same time to improve the "physical plant" of the country by bridges, dams, roads, public buildings and the like; yet no provision is made, in this program, for scientific or engineering research looking toward better public works in the future! ... The picture of such huge expenditures of money and effort for construction, with not even a small provision aimed at technical progress, is heartrending to the creative scientist, engineer, or industrialist, who has come by experience to realize and to take advantage of the permanent value of research. TR

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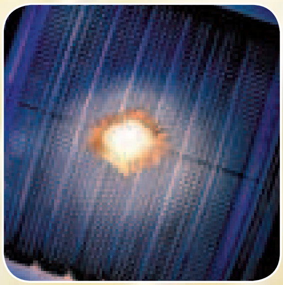

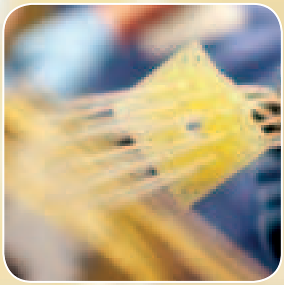


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